GROUND PORK FORMULATED WITH DIETARY FIBER

by

SUSAN L. TODD

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F. E. Cunningham

Major Professor

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Foreword

One of the greatest challenges in new product development is creating food products that appeal to the consumer and are still healthful. The snack food industry spends millions in advertising every year to persuade the consumer that snacking can be healthful. These same companies spend even more in their research and development laboratories producing new products to be test marketed and hopefully put into full scale operations.

Meat products have traditionally been main course items, but the 1980's has brought activity to this relatively sedentary market. New meat products are being developed to combat the recent decline in meat consumption due to health scares concerning fat and cholesterol in a diet with large amounts of red meat. Many of the products being developed provide healthful choices for consumers. Leaner meats and meat products are available that still contain the all so important packages of vitamins and minerals but have done away with the excess fat. Batter and breaded items have gone "lite" by using breadings that absorb less oil and contain sugar substitutes.

Recently, meat products have moved into the snack

food and finger food markets. Many of these products are healthy substitutes for the common candy bar even though there has not been a great reduction in calories. Nevertheless, people are going to snack and industry will always cater to this habit. The challenge of developing a healthful meat based snack food item is what motivated this research project. The topics investigated were:

1) A comprehensive study of available dietary fiber sources and their adaptability to a ground pork system.

2) Sensory and textural parameters of pork patties formulated with dietary fiber.

3) Effect of dietary fiber on the cooking quality of ground pork.

The results of the above experiments and a comprehensive review of the literature are presented in the following thesis.

FIBER: Real Dollar and Sense Opportunities

Fiber containing food products have been recognized as the latest American "fad" foods and as a "hot topic" among nutritionists. Recently however, the "fiber fad" has been fading and the real dollar and sense opportunities are beginning to take shape. Fiber ingredient technology has introduced various methods of controlling, changing and inducing desired textural and sensory properties to fiber engineered products.

Fiber marketing strategists have identified various consumer pools that have a need or desire for high fiber products. Probably the largest and most promising market is found within the diet conscious segment. A women's magazine cited a survey of middle aged women which indicated that 40% of these women are currently on a diet with an added 4% saying that they would like to lose some weight (Farrel et al., 1988). Similarly, a fitness magazine stated that 80% of girls living in California began dieting by the age of 14 (Wooley, 1987). Although these surveys are variable and actual percentages change from article to article, one good point can be extracted. The American population is

concerned with their weight and they are going to diet.

Another population showing interest in high fiber products is the older consumer who is drawn by the health implications of an increased fiber diet. The Kellogg Co. was largely responsible for stimulating this interest with their powerful 1984 advertising campaign for All-Bran breakfast cereal. Although the legalities of the campaign were controversial, they definitely planted a seed of interest when they used the National Cancer Institute's (NCI) statement that linked fiber consumption with reduced cancer risks. This has led to further health claims that show promise for combating high blood cholesterol levels, diabetes, hemorrhoids, diverticulitis, appendicitis, and even obesity through the use of dietary fiber.

An interesting group being targeted as a viable market for fiber products is the Yuppie population. It appears that their demand for premium quality products can be utilized most effectively by the fiber industry. Fiber rich and reduced calorie baked goods manufacturers have already taken advantage of this expanding market and have been readily awarded with rapid sales growth (Aaron and Stauffer, 1986). Few barriers stand in the way of other food industries, such as the beverage and

snack food companies, to follow suit with their own fiber rich products. Developing foods that contain as much nutritional density as possible seems to be the demand of today and of the future. Consumers continue to want their "junk" foods and their "comfort" foods, but they want them to be as healthy as possible. Fiber rich snack foods could easily become as much a reality as the diet colas and low calorie frozen dinners. Why not develop foods such as fiber rich meat and cheese hors d'oeuvres. They may not be the ideal zero calorie diet foods but they could contain appreciable amounts of dietary fiber.

Cellulose and hemicellulose are well recognized fibers that contribute bulk to many of the products in which they occur. They are inert substances that are often used to add solids to a product without adding calories. Another added bonus is that they are usually colorless and flavorless. Cellulose is available in many different grades or granulation sizes which affects its water absorption capabilities. In general, as the particle size decreases, fewer water binding sites remain available, resulting in less water holding capacity. However, the smaller particle size is less detectable in food systems. Pure cellulose, also known

as alpha cellulose, is currently being used as a replacement ingredient for fats, oils and simple sugar carbohydrates. Fiber rich bakery items which have utilized these insoluble substances have long been available in the form of breads, crackers, cakes and cookies. The breakfast cereal market has also provided the consumer with a wide variety of high fiber choices. But the fiber story does not end there. Cellulose and hemicelluloses are also being used for various reasons in sauces, gravies, spices, pasta products, dry beverage mixes and cheese analogs.

Cellulose is often modified by chemical means to provide ingredients that exhibit similar or very different physical properties from the original source. Carboxymethylcellulose (CMC), methylcellulose, hydroxypropylcellulose and microcrystalline cellulose (MCC) are some of the commonly used derivatives. Applications of these ingredients are widespread and depend upon the ingredient's physical properties. CMC is a common viscosity modifier and stabilizer for dairy and nondairy products and for frozen novelty items. Methylcellulose also functions as an emulsifier and stabilizer but due to its unique solubility properties is often aimed at the fried food market. It is used to

reduce oil migration and to retain moisture of fried foods. MCC, marketed under the trade name of Avicel, is a popular ingredient in low calorie products such as reduced calorie salad dressings, imitation mayonnaise, nonfat frozen desserts and nondairy bakery fillings. It also has shown compatibility as an ingredient for high fiber, high protein, dry blended beverage mixes. Recently, a fiber-containing skim milk product was introduced by Amstell Inc. (Marietta, Ga.). They used a colloidal type of microcrystalline cellulose to contribute noncaloric solids to skim milk making it taste, they claim, like an ordinary whole milk. Hydroxypropylcellulose is recognized for its surfactant properties and film forming capabilities. This substance is also compatible with other fibers such as gums and other cellulose derivatives. In fact, many of the commercial fibers with specified trade names are made with various combined fibers. However, one must carefully check specification numbers and any literature accompanying fiber samples to be sure what fiber(s) they are dealing with.

Applications for the soluble, food gum fibers has recently increased and the food companies are capitalizing on the fiber claims they have pushed into

their marketing strategies. The soluble fibers work best in liquid foods such as drinks, soups, low viscosity sauces and related condiments. Two gums have quickly jumped into the lead due to their physical properties and most importantly, their reasonable costs. Gum arabic, a gum extracted from Acacia trees, tops the demand list. It is low in viscosity, odorless, tasteless, high in fiber and costs around $0.008 per gram soluble fiber. This gum was tested in commercial drinks (eg. iced tea, strawberry drink, orange drink) and soups (eg. chicken noodle, mushroom, and chicken) by a sensory panel which found no perceptible taste change with up to 3 grams added fiber/ 8 oz. serving (Andon, 1987). In second place is CMC, the soluble cellulose derivative discussed earlier. This cellulose gum comes the closest to matching the viscosity patterns of gum arabic. The real importance for this gum is its economic advantage. Since it is manufactured from a widely available source (cellulose) instead of being extracted from a limited source such as gum arabic, CMC is more cost effective at $0.004 per gram (Andon, 1987). However, the Food and Drug Administration (FDA) states that CMC is not a natural ingredient, thus limiting its usage.

We can not overlook the natural fruit and vegetable fibers or the various grain fibers as additional fiber sources. However, more problems are present with these ingredients in respect to their physical properties. They carry distinctive flavors that are hard to mask and many are gold to brown in color. However, some bran and fiber processors have corrected these problems and are producing white to colorless products with minimal flavors. Unfortunately, the problems do not end here. The total dietary fiber content for these natural products is lower than the celluloses and in many cases quite a bit lower. Furthermore, these ingredients tend to be more expensive than the popular celluloses and their derivatives.

Promoting health and preventing disease is a national objective that is followed closely by the food industry. This should not be too surprising since most health and disease issues, if not related directly, will eventually come back to the eating habits of the individual. Many food product developers are gearing their new ideas toward the 1990 National Nutrition Objectives (USDA/DHHS, 1985) which include among others the goals of improved health status, reduced risk factors and increased public awareness. In summary, one

of the 1990 objectives is to have 70% of adults to be able to identify the major foods which are low in fat content, low in sodium content, high in calories, and good sources of fiber (Nestle, 1988). It is this objective that will most likely sell new products formulated with fiber rich ingredients.

CHEMICAL COMPOSITION

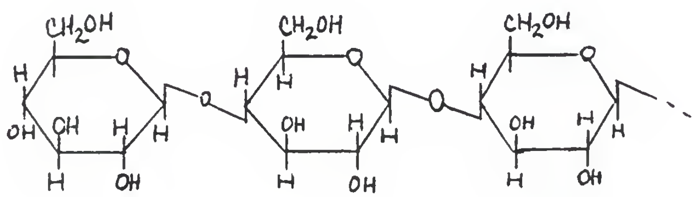
Dietary fiber is a complex matrix of components that act individually and in combination to propagate a physiological response. Chemically speaking, the components under consideration are cellulose, hemicellulose, pectic substances, gums, and lignin. Often, these components are grouped into categories based on similar inherent properties. Currently the grouping methods seen in the literature include structural classifications such as polysaccharide / nonpolysaccharide sources, solubility differences, and even cellulose / noncellulose groupings. With so many different ways of classification available, one can become rather confused on what component yields what function. Therefore, hopefully any confusion can be resolved by discussing each component individually.

Cellulose is the component most commonly associated with the dietary fiber term, since it is the most abundant carbohydrate in nature. It is the principal structural component of the plant cell wall, accounts for nearly half of a plant's weight, and contributes to the characteristic texture of plants we use as food. Cotton is a good example of a plant product composed of nearly pure cellulose. The skins of fruits and

vegetables also contain significant quantities of this component. As fruits and vegetables mature, the amount of cellulose tends to increase.

In its natural form, cellulose is insoluble in water and cannot be digested in the human gut. It is composed of B-1,4 linked linear chains of D-glucose which may total as many as 10,000 units (Figure 1). The linearity of this component makes it easy for molecules to associate strongly in a parallel manner. This forms the firm structural skeletons found in trees and the woody part of various other plants (Whistler and Daniel, 1985).

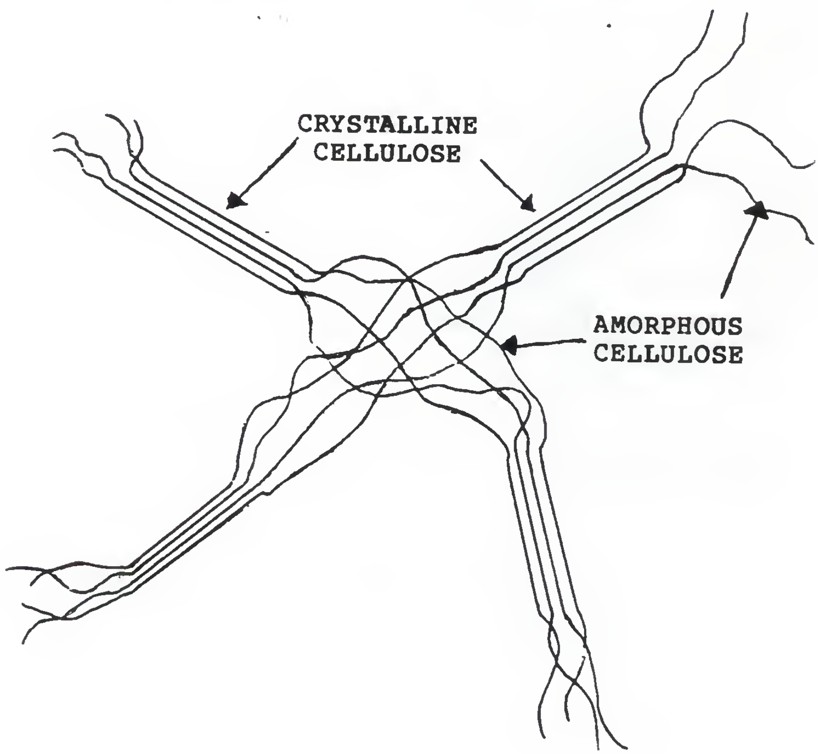
FIGURE 1: CELLULOSE CHAIN FRAGMENT



The cellulose structure has crystalline regions and areas of disorganization called amorphous cellulose (Figure 2). In the crystalline regions, the chains are

held tightly in parallel configuration by hydrogen bonds. However, a much looser arrangement occurs in the amorphous segments which allows for water absorption and consequent swelling. These amorphous regions are also believed to be flexible and capable of bending without breakage. If true, this shows the unique value of the cellulose fiber, strengthening a stem or leaf and yet maintaining a degree of flexibility which prevents fracture (Meyer, 1982).

FIGURE 2: AMORPHOUS AND CRYSTALLINE CELLULOSE



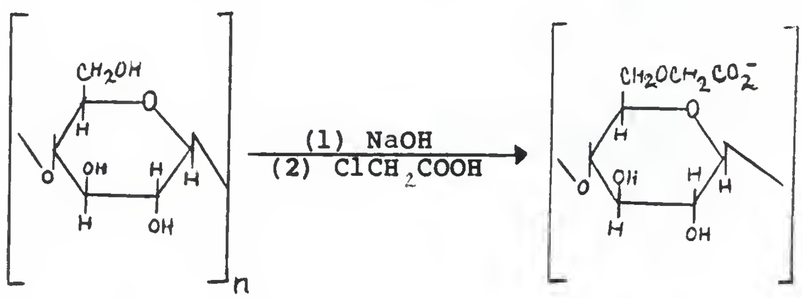
The noncrystalline regions of the chain are attacked first by solvents and chemical reagents which are often used in the food and chemical industry to convert native cellulose to one of its many derivatives. These derivatives can exhibit very unique physical properties or may mimic the properties of some other component such as a gum or pectic substance. Therefore, it is important to examine the chemical make-up of each of these ingredients before using them as an additive.

Microcrystalline cellulose (MCC), a common cellulose derivative, is made by hydrolyzing the noncrystalline regions with acid. Commercially marketed under the Avicel trade mark, this insoluble product is used as a nonmetabolizable, bulking and rheological control agent in low-calorie foods (Whistler and Daniel, 1985). As MCC is used more widely as a food ingredient, new and different functional properties become necessary. Thus, it is often chemically modified or combined with other fibers to obtain the functions desired. One specific type has been developed by blending a colloidal form of MCC (Avicel) with sodium carboxymethylcellulose and then dried. When properly dispersed in water, the individual particles disintegrate and form a dispersion of cellulose

microcrystal aggregates. These aggregates make up the resulting opaque thixotrophic gel which has the stability and compatibility of the original MCC polymer with the elasticity and yield value of the solid dispersed microcrystals.

Cellulose-based food gums are also used widely in industry. Carboxymethylcellulose (CMC) and methyl cellulose are the most popular. They are water soluble ethers of cellulose and are used as thickening and bulking agents. Figures 3 and 4 show the chemical formulas for the preparation of these two cellulose gums. Although CMC and methyl cellulose are derived from an insoluble and indigestible source, one must remember that they behave similar to the water soluble gums.

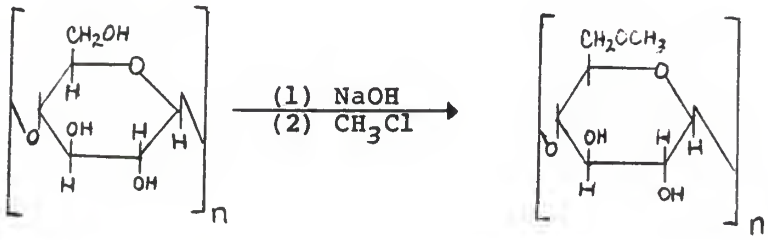
FIGURE 3: PREPARATION OF CARBOXYMETHYLCELLULOSE



CELLULOSE

CARBOXYMETHYCELLULOSE

FIGURE 4: PREPARATION OF METHYLCELLULOSE



CELLULOSE METHYLCELLULOSE

Hemicellulose is defined as a plant polysaccharide extracted by aqueous alkali. This definition omits the water soluble polysaccharides, often classified as acid hemicelluloses, which will be discussed later. Hemicellulose yields pentoses, glucuronic acids, and some deoxy sugars upon hydrolysis. The intact structure usually consists of a B-1,4 linked xylan backbone with arabinose, galactose, and glucuronic acid side chains. Less prevalent hemicellulose fibers also exist with mannose, galactose, and glucose included in their backbone chain (Schneeman, 1986; Whistler and Daniel, 1985).

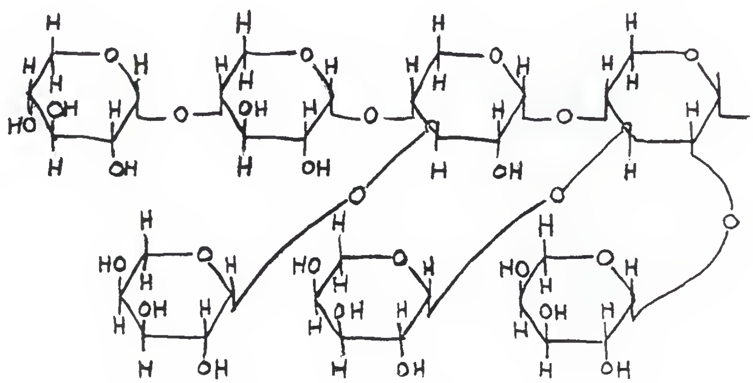
Hemicelluloses are distinguished from cellulose by the characteristic fewer sugar units per molecule. Chain lengths range from 50-200 units (Analytical Progress, 1985) whereas cellulose chains range in the

thousands. Celluloses are fibrous molecules made of D-glucose units while hemicelluloses are nonfibrous and yield D-xylose and other sugars upon hydrolysis. Hemicelluloses are also more readily hydrolyzed by dilute acids and are more soluble in alkali than the celluloses. However, hemicelluloses display a wide range of solubilities often dependent upon the number of side chains. Generally, the more side chains present, the greater the solubility.

Hemicellulose is often classified as a noncellulose polysaccharide which also encompasses the gums and pectic substances. Frequently all these components occur in foods and plants as complexes intricately associated by physical and covalent bonds. Therefore, hemicelluloses isolated for study have generally been from wood sources, but the recent interest in fiber containing foods has stimulated the study of this component and the foods which contain it. Wheat and oat straw are good sources along with wheat flour and corn cobs. Figure 5 shows a portion of wheat flour hemicellulose that demonstrates the typical xylose residue back bone. This particular hemicellulose has branching arabinose moieties on either carbon 3 or occasionally carbon 2. Fruits and vegetables also

contain fractions of hemicellulose. Pears are a good fruit source while sugar beet fiber has recently been advertised as a fiber ingredient containing 32% hemicellulose.

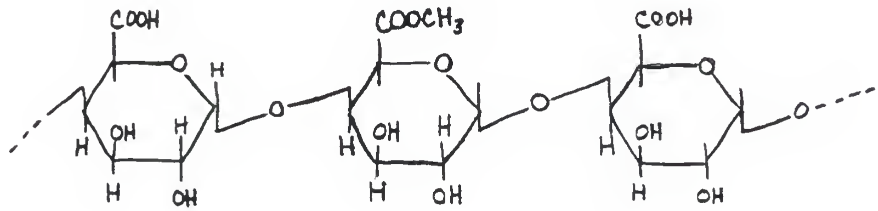
FIGURE 5: **WHEAT FLOUR HEMICELLULOSE**



Pectic substances are found in the middle lamella of plant cells and are involved in the textural changes that occur in fruits and vegetables upon ripening. These polysaccharides consist of galacturonic acid units joined with α - 1,4 linkages. The side chains may contain the sugars rhamnose, arabinose, xylose and/or fucose (Schneeman, 1986). Figure 6 shows a portion of a pectic substance chain. The angle between the 1- and 4-carbons is 90 degrees to the plane of the galacturonic

acid ring. Thus, this chain differs from other polysaccharides because this particular angle gives the linear unit a screwlike configuration (Meyer, 1982).

FIGURE 6: PECTIC SUBSTANCE CHAIN FRAGMENT (PECTIN)



Several types of molecules are derived from combinations of the above sugars. Protopectin, pectinic acids, and pectic acids are the most common forms. These substances differ in the degree to which the galacturonic acid residues are esterified with methanol. Protopectins are highly esterified compounds and are insoluble in water. They make up the flesh of immature fruits and vegetables and are responsible for the hard texture found at this stage of maturation. They are often termed the parent pectic substance since upon restricted hydrolysis they yield pectinic acids. Pectinic acids are less highly methylated and may be colloidal or water soluble in nature depending on the

degree of methylation. Various pectin molecules occur in this group and are widely utilized for their gel forming characteristics. Pectic acids are colloidal polygalacturonic acids and are subsequently formed upon complete removal of the methyl ester groups (Meyer, 1982).

Carbohydrates such as cellulose, hemicellulose, and pectin do not yield sugars upon digestion in the human gut. They are, therefore, considered unavailable substances. However, the products they do produce provide energy in the form of volatile fatty acids. The main acids produced are acetic, propionic, and butyric which are readily absorbed by man (Van Soest, 1978).

Gums are water soluble polysaccharides that occur in plants and microorganisms. They are well recognized for their viscosity inducing capabilities and for their gelling contributions. There is a great variation in the sugars that compose these fibers and the order in which they occur. The main chains are often composed of galactose or as repeating units of two different sugars such as galactose-mannose, glucose-mannose, arabinose-xylose, or galacturonic acid-rhamnose. Xylose, fucose and galactose are the most frequently occurring side chain sugars (Schneeman, 1986).

Guar and locust bean gums are seed galactomannans while gum arabic and gum tragacanth are plant exudates. Other gums include carrageenan, alginate, dextran, xanthan, and oat gum. Oat gum is primarily composed of beta-glucan which is also found in barley. These compounds impart a variety of physical properties to foods. Often used as stabilizers in salad dressings, puddings and ice cream, they are also used as crystal inhibitors in confections, flavor fixatives in beverage mixes and as dough conditioners.

Lignin is inert, insoluble, and resistant to digestion (Southgate, 1976). It's three dimensional structure is intricately composed of sinapyl, coniferyl and p-coumaryl alcohol. This nonpolysaccharide is present in foods in less abundance than the other polysaccharide fibers, but it does occur in fruits such as strawberries and pears and also in the bran of some cereal grains. As a plant matures, the amount of lignin increases and hardens. It then acts as a cement for the cell wall and the associated constituents (Analytical Progress, 1985).

METHODS OF ANALYSIS

Dietary fiber is defined by many as plant materials which are resistant to the digestive enzymes secreted by higher animals, including man. One should keep in mind that substances which are resistant to the secreted enzymes are termed unavailable but not indigestible. Many fibrous carbohydrates are unavailable but are digestible in that they disappear through fermentation in the large bowel (Van Soest, 1978).

According to its definition, a total dietary fiber measurement should contain all of the cellulose and hemicellulose along with the lignins, pectic substances and gums that encrust the cell walls. Theoretically, this is also crude fiber. However, the quantity of fiber actually found is dependent upon the method of analysis.

Several different methods are available for determining fiber content. Crude Fiber Analysis is the former AOAC official method (AOAC 7.071 14th Edition, 1984) which is based on the extraction with acid and alkali. During this process, some compounds are hydrolyzed along with the fat and protein removal. Therefore, this procedure does not accurately estimate

the dietary fiber content of foods and actually produces the lowest values of all the available methods of determination. More specifically, cellulose and lignin fractions and soluble fibers are underestimated (Schneeman, 1986).

The Acid Detergent Fiber (ADF) method was developed in the early 1960's. This method, devised by Van Soest to improve the recovery of true fiber components, is a rapid extraction method using an acid and a detergent. Higher values for cellulose and lignin are obtained, especially for the lignin fraction. Thus the method was approved in 1975 by AOAC (AOAC 7.074 14th Edition).

Similar to the ADF method, the Neutral Detergent Fiber (NDF) method was also developed by Van Soest for his study of fiber content in animal feeds. NDF is also a rapid extraction method that is useful for estimating the content of insoluble structural polysaccharides and lignin. Basically, NDF estimates the structural components of the cell wall such as cellulose, hemicellulose, and lignin. The soluble fiber sources such as gums and pectin must be estimated by other methods. This method, originally developed for analysis of animal forages, has since been modified for foods containing high percentages of fat, protein, and starch

(Schaller, 1977). This modified NDF is the adopted method of the American Association of Cereal Chemists (AACC).

Recently, the need to know the total quantity of fiber in a food substance has brought about a new approach of analysis. Individual fiber components can now be determined and combined to present an accurate and complete picture of the fiber found in a system.

The Southgate procedure approaches the problem of total dietary fiber determination by removing individual fractions through a series of extraction steps (Southgate, 1976). The fractions are then hydrolyzed and sugar components determined by liquid or gas-liquid chromatography. This method is very rigorous and time consuming but also very accurate.

The Rapid Enzymatic Procedure (Prosky et al., 1984) provides a single value for the soluble and insoluble fiber content of the food (total dietary fiber). Fat is first extracted from the food and then protein and starch are removed enzymatically. Starch is thought to interfere with the analysis if not digested first. The residue is corrected for ash and residual protein content, and the fiber is determined gravimetrically. Testing shows that the more fiber in a product, the

lower the coefficients of variation. This is a rapid method but does not identify individual fiber components. However, all of the fiber fractions are included as part of a total fiber estimation. Currently, this procedure is under review and likely to be approved by the AOAC. If approved, this would provide a more accurate means for reporting total fiber content.

FIBER PHYSIOLOGY

Individual fiber components have inherent physical properties that many researchers have attempted to correlate with physiological responses in humans and experimental animals. Naturally occurring fiber, such as that found in seed grains and fruits, is composed of many different fractions of fibrous materials. Each of these fractions has certain physical properties that may or may not be shared with the other fractions. For instance, most polysaccharide fibers have the ability to be degraded by bacteria whereas only the polysaccharides with functional polar groups have water-binding capabilities. Table 1 summarizes some of these properties and the physiological responses brought about by specific fibers.

Bacterial degradation of fiber is a physical property that occurs through fermentation of the polysaccharides in the large bowel. The extent of breakdown depends on the physical structure of the plant and the type of polysaccharides available. The degree of degradation is important because as short-chain fatty acids are formed, their resulting by-products influence physiological responses (Pomare et al., 1985).

TABLE 1: Physical Properties and Physiological Responses of Certain Fiber Fractions. (Kay, 1982)

Physical Property	Fiber Fraction	Responses
Bacterial degradation	Polysaccharide	Production of short chain fatty acids, flatulence, and acidity
Water-holding capacity	Polysaccharides with polar groups	Effect on nutrient absorption, fecal weight, and rate of transit in stomach and small intestine
Adsorption of organic materials	Lignin, pectin	Binding and excretion of bile acid
Cation exchange	Acidic polysaccharides	Increase in mineral excretion

Furthermore, as fibrous substances are fermented the pH of the bowel may increase, thus possibly affecting microbial metabolism.

The water binding capabilities of certain fibers have been of great interest in the food industry. Increasing bulk and preventing weepage in meat products by enhanced binding qualities carries great economical advantages for both the consumer and processor. The pectins and mucilages have the greatest water binding properties due to their sugar residues with free polar

groups. Since hydration of these components results in a gel matrix which increases the viscosity of the small intestinal contents, it is thought that nutrient absorption is slowed. Presumably, diffusion of nutrients for absorption will be slowed by the partitioning of water soluble nutrients into the gel matrix and by the increase in viscosity of the intestinal contents (Schneeman, 1986).

Organic molecules adsorbed by dietary fibers include the bile acids, cholesterol and toxic compounds. Lignin is probably the best adsorbent for bile acids followed by pectin and other acidic polysaccharides. However, cellulose has very little if any adsorbent properties for organic molecules. It has been proposed that some fibers bind toxic compounds as a protective mechanism of the fibers against gastrointestinal cancers.

The degree of cation exchange possible with certain fibers influences the availability of minerals and electrolytes. Diets excessively high in dietary fiber tend to reduce mineral and electrolyte availability due to the binding of these molecules to the fiber sources. As a result, many of the minerals and electrolytes are excreted instead of absorbed. Studies have shown that

the number of free carboxyl groups on the sugar residues and the uronic acid content of polysaccharides appear to be related to the fiber's cation exchange properties (Schneeman, 1986).

PHYSIOLOGICAL EFFECTS

The physiological responses induced by the physical and chemical properties of dietary fiber have been the subject of intense study for the past fifteen to twenty years. In the early seventies, interest in this dietary component was stimulated by the work of two British physicians. Dr. Hugh Trowell (Trowell, 1972) and Dr. Dennis P. Burkitt (Burkitt, 1973) published reports noting that in countries where diets included large amounts of fiber, there were fewer cases of colon and rectal cancers, diverticulosis and other benign internal diseases. Further studies conducted on rural African groups indicated that other internal diseases such as appendicitis, gallstones, varicose veins, some forms of coronary heart disease and diabetes all occurred with much less frequency in the African populations than in the industrialized Western civilizations. These findings led to more food consumption studies which associated a prolonged lack of dietary fiber in the diet to a spectrum of unrelated non-infectious diseases

(Burkitt, 1969; Burkitt, 1973; Cummings, 1973; Tunaley, 1974). This resulting spectrum has been divided into three categories; 1) diseases of the gastrointestinal tract, 2) circulation related diseases, and 3) metabolic diseases. Since the seventies, additional studies have strongly indicated that fiber is indeed related to such intestinal diseases as chronic constipation, diverticulosis, and a condition known as "irritable bowel syndrome." Other work has shown dietary fiber to be helpful in controlling obesity, depressing some forms of diabetes, and lowering blood cholesterol levels. All of these conditions are related to coronary heart disease, one of the major causes of deaths in the United States and other developed countries. Table 2 shows the diseases that have shown a relationship to dietary fiber consumption.

However, as with most epidemiological data, the relationship between diet and disease must be considered carefully and the complex variables underlying the data must be accounted for and controlled. For example, diets rich in fiber are typically lower in fat and protein levels. Also the differences in environments between developed and underdeveloped regions of the world add an additional factor to the results of

TABLE 2: Diseases Shown to Have Some Relationship to Deficient Dietary Fiber Intake

GASTROINTESTINAL	CIRCULATION RELATED	METABOLIC
Constipation	Atherosclerosis	Obesity
Hernias	Coronary heart disease	Diabetes mellitus
Varicose veins	High blood cholesterol	
Deep vein thrombosis		
Hemorrhoids		
Diverticulosis		
Appendicitis		
Colon cancer		

Burkitt's and Trowell's studies. So we see that the relationship between dietary fiber and disease is still not proven due to many underlying and uncontrollable variables. However, recent studies have been convincing enough for the U.S. Department of Health and Human Services and U.S. Department of Agriculture to come forward and suggest that the public should keep adequate quatities of fiber in their diet. In the 1980 "Dietary Guidelines for Americans" these two agencies advised the following:

> "The average American diet is relatively low in fiber. Eating more foods high in fiber tends to reduce the symptoms of chronic constipation, diverticulosis, and some types of `irritable bowel.' There is also concern that low-fiber diets might increase the risk of developing cancer of the colon, but whether this is true or not is not yet known."

Furthermore, in August of 1984, Peter Greenwald, Director of the Division of Cancer Prevention and Control, National Cancer Institute (NCI) addressed this issue by the following statement:

> "Research data suggesting that fiber-containing foods provide some protection against colon and rectal cancer have led the National Cancer Institute to make recommendations now, that Americans eat a diet high in fiber from whole grain breads and cereals and fresh fruits and vegetables. If followed, these recommendations may reduce individual risk of these cancers." (Analytical Progress, 1985).

The question facing scientists today is how to tie the dietary fiber's physical properties to the physiological responses of disease. Four effects have been studied in detail.

Increased fecal weight and bulk is likely to be the best response known among the general public. Often doctors will prescribe a higher fiber diet for those suffering from constipation or else prescribe a commercially available laxative. Actually, most laxatives have various fibers as their base ingredient. The water-holding abilities of many fiber constituents not only increase fecal weight but also promote colonic peristalsis which propels the colon's contents faster (Scala, 1974). The decreased transit time, due to the increase in bulk, is thought to partially protect from

colon cancer since the bile acids are in contact with the colon tissues for less time.

Only the fibers that have an indigestible residue will decrease transit time. Sources such as cereal brans are effective in this respect. Coarsely ground wheat bran is one of the best sources since it has the ability to increase wet weight by 80% to 120%. However, grinding the bran to a finer texture disrupts the physical structure and results in reduced bulking action (Schneeman, 1986). The exception in this case is cellulose. Cellulose, a relatively unfermentable source, has very little effect on increasing fecal weight (Scala, 1974). Neither do the highly fermentable fibers of fruits and vegetables, such as apples and cabbage, have any effect on fecal volume or transit. The pectin fibers found in these foods are normally completely fermented in the large bowel. However, lignin has quite the opposite effect in that it has been found to be constipating.

A reduction of blood cholesterol levels has been indicated by many fiber studies. Both animal and human data collected in this area support this claim (Cummings, 1983; Trowell, 1972). The proposed mechanism of action is that water soluble fibers bind the bile

acids so they are excreted. This action decreases the amount of bile acids available for absorption and results in an imbalance. The body compensates by synthesizing more bile acids from available blood cholesterol (Analytical Progress, 1985). Due to differences in chemical composition, fibers differ in their binding abilities. The noncellulose polysaccharides tend to be most effective in reducing plasma-cholesterol levels (Anderson and Chen, 1983). Examples of these types of fiber sources are beans, guar gum, pectin, oat bran, and rolled oats (Anderson and Chen, 1983; De Groot et al., 1963). Some gums have also been credited for lowering the low density lipoprotein levels while leaving high density lipoprotein levels unchanged. Since these compounds don't bind bile acids, due to their neutrality, some other fiber mechanism must be responsible for this lowering effect (Reiser, 1984).

High blood cholesterol levels are considered one of the primary risk factors in atherosclerosis and coronary heart disease. One might interpret this proposed relationship between fiber and cholesterol levels as a prescription for preventing these conditions. However, many factors play a determinative part in the occurrence of atherosclerosis and coronary heart disease.

Therefore, the fiber role may be only a small segment of a much larger preventive regimen. For this reason, scientists and health agencies have reserved their judgments until further developments and studies concerning this issue have been completed.

The physical properties of dietary fiber also have been used to help control metabolism related diseases such as diabetes mellitus and obesity. Evidence suggests that by increasing the viscosity of the diet through fiber utilization, the carbohydrate diffusion rate in the gut is decreased and the stomach empties slower. Furthermore, the diffusion and absorption of nutrients, enzymes, and substrates in the intestinal tract is possibly altered. Current reports suggest that during the digestive phase, hydrolysis and diffusion is slowed and during the absorptive phase, the cell surface and transport mechanism is altered (Schneeman, 1982; Schneeman and Gallaher, 1985). Diabetics administered high carbohydrate - high fiber diets show that glucose tolerance is improved in noninsulin requiring diabetics (Reiser, 1984) and a significant reduction and even withdrawal has been documented for those individuals dependent upon insulin (Jenkins et al., 1980). In contrast, high-carbohydrate diets low in dietary fiber

showed no quantitative improvements in glycemic control within diabetic subjects (Hollenbeck et al., 1983).

Obesity is sometimes treated with high fiber diets because of the fiber's ability to act as an obstacle to energy intake. The act of displacing nutrients from the diet, reducing the absorptive efficiency of the small intestine, requiring increased eating time and providing bulk in the stomach which provides a feeling of fullness have been offered as the probable mechanisms (Heaton, 1973; Stephenson, 1985).

Many of the soluble gums are effective for treating these two disorders. Guar gum and the beta-glucan component of oat bran (oat gum) are cited as effective fibers as well as cellulose (Miranda and Horwitz, 1978). More importantly though, a diet containing adequate quantities of foods such as celery, salad greens, apples and other citrus products should provide the individual with all the dietary fiber components that are important for preventing the onset of obesity and some forms of diabetes. Again, keep in mind that fiber itself isn't a foolproof preventive agent against conditions such as these which can be induced by many factors.

One of the problems nutritionists and doctors face in recommending increased levels of fiber consumption is

the occurrence of decreased nutrient availability. Minerals such as iron, zinc, calcium, copper, and selenium may be bound by fiber causing them to be excreted instead of absorbed. However, in a detailed report by Toma and Curtis (1986); iron, zinc and calcium were not significantly absorbed by various dietary fibers which were added at levels between 20-24 g./day. However, some inconsistencies in results can be found in the literature. Several explanations for these differences exist. The method of fiber analysis controls the amount of fiber determined to be present. Although most studies specified neutral detergent fiber analysis, many others were reported only as grams of dietary fiber. As discussed earlier, results from different methods of analysis can not be used interchangably. The particular fiber being tested for mineral absorption also plays a significant part since fiber sources vary in their physical and chemical properties which effect their mineral binding capabilities.

The phytate concentration of fiber has been under scrutiny for some time and has led to many studies that have investigated its relationship to mineral absorption. Phytates can form insoluble complexes with

iron (O'Dell, 1983; Spiller, 1980) and possibly with zinc. A study investigating the effect of phytates on zinc bioavailability in animal subjects resulted in no significant effect on zinc absorption from two brans containing different phytate levels. However, when wheat bran, corn bran, soy bran, oat hulls, rice bran, and cellulose were added at 6% to animal diets, the fiber highest in phytate, the rice bran, reduced zinc concentrations significantly (Thompson and Weber, 1981). Zinc bioavailability was greater in refined grain products than for whole grains and wheat bran which again suggests that phytate is acting as a chelator (Erdman, 1981).

Nevertheless, human studies have not shown any significant relationship between phytates and mineral absorption. Morris (1983) stated that in humans the presence of phytate did not seem to affect absorption of iron. Van Dokkum et al. (1982) and Rattan et al. (1981) found that wheat bran had no effect on serum zinc levels in humans. A negative zinc balance finally occurred when fiber concentrations reached 35 g. NDF/day.

The binding of calcium may be a more serious problem than the other minerals discussed. Fiber seems to affect calcium more readily by causing partial

erosion of the epithelial surface of the intestinal mucosa which destroys some of the calcium-binding proteins. This in turn reduces the calcium absorption from the intestine (Toma and Curtis, 1986). However, human studies still have not shown any adverse effects on calcium absorption until levels are increased to 35 g NDF/day (Van Dokkum et al., 1982).

Overall, the message that professionals are giving the general public concerning fiber is that this once nonessential nutrient is starting to claim more and more importance in regard to good health. They are recommending that consumers add more fiber to their daily diets but are warning against overindulgence. Unless prescribed by medical professionals, fiber pills or supplements are regarded as unnecessary. There is more than enough fiber available in our everyday foods as long as the individual eats regularly of the four food groups and has knowledge of the fiber rich products.

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Paper 1

PRELIMINARY STUDIES:
Sensory Screening of Fiber in Ground Pork Patties

S.L. Todd, F.E. Cunningham, J.C. Claus
and M.C. Hunt

Department of Animal Sciences and Industry
Kansas State University
Manhattan, Kansas 66506

Contribution No.   , Department of Animal Sciences
and Industry, Kansas Agricultural Experiment Station,
Manhattan, KS 66506

ABSTRACT

Twenty eight sources of dietary fiber were incorporated into a ground pork product and analyzed by a sensory panel on an accept/reject basis. Flavor, color, and texture comments were summarized and recorded. Products made with Solka-Floc SW-50, BW-60, and BW-300 (James River Corp.) were all acceptable at 3.5% but were rejected at 10% . Patties made with 3.5% hydroxypropylmethyl cellulose (Zumbro Corp.) and microcrystalline cellulose RC-591 and CL-611 (FMC Corp.) also were very acceptable. Although most products made with soluble fiber sources were rejected, the product containing Nutriloid Colloid 710 (TIC Gums) was accepted at 3.5% . The products containing grain, fruit or vegetable based fibers were rejected due to the off-flavors imparted by these sources.

INTRODUCTION

Due to the increasing concern with dietary fiber and the importance of this nutrient in the diet, many industries are trying to market dietary fiber additives for the food industry. Corporations such as James River and FMC are even conducting their own research on fiber formulated food products. Solka-Floc (James River Corp.) has been experimentally added to breads and pastries, cereals, sauces, pasta, canned meat products, imitation cheese products and powdered beverage products. Bacus (1986) reported successful utilization of Solka-Floc in cooked sausage, canned meat products and mechanically deboned meats such as poultry, beef and pork. FMC Corp. has formulated products with fiber such as low calorie confections and dairy products and have tested fiber-added fine grind meat emulsions (Ayling, 1985).

The objective of this study was to screen, by sensory methods, various fiber sources that had been blended in fresh ground pork.

MATERIALS AND METHODS

Table 1 contains the fiber ingredients tested and the supplier from which they were obtained. Table 2 contains the flow chart which describes the procedure

TABLE 1: Fiber ingredients incorporated into ground pork for sensory screening.

	INGREDIENT	SPECIFICATION	SUPPLIER
1.	Pure cellulose	SW 50 m	James River Corp.
2.	Pure cellulose	BW 60 FCC	James River Corp.
3.	Pure cellulose	BW 300 FCC	James River Corp.
4.	Pure cellulose	Fine granular	James River Corp.
5.	CMC	Fine 15	TIC Gums
6.	CMC	R STD 700	TIC Gums
7.	CMC	Fine 4500	TIC Gums
8.	HPMC / maltodextrin	HPMC-10	Zumbro
9.	Methylcellulose		Dow Chemical
10.	MCC	RC-591 F	FMC Corp.
11.	MCC	CL-611	FMC Corp.
12.	Nutriloid	Guar Fine	TIC Gums
13.	Nutriloid	Guar Coarse	TIC Gums
14.	Nutriloid	Fiberplus	TIC Gums
15.	Nutriloid	Colloid 710 H	TIC Gums
16.	Vegetable Fiber		Dupro
17.	Soy Fiber		Grain Proc. Corp.
18.	Apple Fiber		Canadian Harvest
19.	Barley Fiber		Canadian Harvest
20.	Corn Fiber		Canadian Harvest
21.	Oat Fiber		Canadian Harvest
22.	Rice Fiber		Canadian Harvest
23.	Wheat Fiber		Canadian Harvest
24.	Hi-Fi Lite		Canadian Harvest
25.	Micro Snowite Oat Fibre		Canadian Harvest
26.	Purified Bran		Fisher
27.	Rice Bran		Riviana Foods
28.	Yellow Vegetable flour		Dupro

CMC = carboxymethylcellulose
HPMC = hydroxypropylmethylcellulose
MCC = microcrystalline cellulose

followed for making the ground pork patties with added fiber source. Table 3 contains the flow chart describing the preparation of the meat sample for screening. A taste panel composed of experienced Meat Science and Food Science Professors and Graduate students at Kansas State University screened the products on accept or reject basis only. Panelists were first given a control product consisting of ground pork without fiber as a warm-up sample. An identical control product was given next to each panelist. The panelists were instructed to use the control as a point of reference when evaluating the test samples. They were also asked to comment on their reasons for rejection (Figure 1). On several of the samples a "maybe" indication was given on the basis that although the product was not acceptable as it was, the panelist felt it could be manipulated through the preparation process into an acceptable product or the off-flavor present could be suitably covered or masked. Therefore, those samples with this indication were placed in a "maybe" category.

RESULTS

Following is a detailed table (Table 4) containing fiber source, number of accept, reject or maybe scores,

TABLE 2: PROCEDURE FOR GROUND PORK PATTIES WITH ADDED FIBER SOURCE

1. Boneless frozen pork picnics (80/20)
   Source: Flint Hills Foods
   * Thaw 72 hours at 2°C

2. Grind through 3/4 in. plate
   (Hobart Grinder - Model 4812)
   * Mix 1 minute (Leland Food Mixer - Model 100 DA)

3. Fat Analysis (Hobart Fat Tester)
   * Adjust to 20 $\pm$ 2% fat content

4. Vacuum package (Smith Super Vac - Temperature : 5, Vacuum : 7)
   * 4-8 lbs units

5. Blast freeze (0°C)
   * store 1-7 days at 0°C

6. Thaw 4-8 lbs packages 24 hrs. at 2°C

7. Grind meat through 1/4 in. plate (Hobart grinder)

8. Flatten meat block with hand. Based on the meat block weight, add salt (1%) and phosphate (0.3%) mixture by sprinkling evenly over meat. Mix into meat briefly with hands.
   * Phosphate: Stauffer Chemical CuraFos 22-4,
     Westport, CT.

9. Grind meat, salt and phosphate through 1/4 in. plate

10. Add test ingredient (unhydrated)
    * 3.5% or 10.0% fiber ingredient based total dietary fiber composition of ingredient.
    * Mix 1.5 minutes
      (Kitchen Aid Mixer -Model K45SS ; Setting - 1 ;
      Attachment - Flat beater)

11. Vacuum package and blast freeze (0°C)
    * Store at 0°C until ready for taste panel

TABLE 3: PANEL PREPARATION FOR GROUND PORK PATTIES WITH ADDED FIBER SOURCE

1. Thaw samples 10-12 hrs. at 2°C.

2. Weigh out 85 grams of meat sample
   * Press into uniform patties (9 cm. diameter; 1.1 ± 0.1 cm. thickness) with hand press.

3. Place patties on wire racks of broiling pans (pre-sprayed with Pam non-stick coating spray) 6 patties per pan.

4. Oven broil in 190.5 ° C (375°F) preheated rotary oven for 50 min.
   * Turn patties at 25 min.

5. Cut patties into 8 pie shaped wedges and place each sample (8 wedges) in small individual double boiler pans (bottom water temperature approximately 50°C).

6. Set samples on heated serving tray (low setting) and keep them there until served to panelists.

FIGURE 1: Taste panel form for preliminary screening of fiber sources.

NAME:________________ DATE:________________

SAMPLE #	ACCEPT	REJECT	COMMENTS
CONTROL			
71			
18			
44			
48			
63			
21			

FLAVOR	COLOR	MOUTHFEEL
Off-flavor	Dark	Mealy/grainy
Off-odor	Light	Oiliness
Different flavor	Green	Tacky
Pork flavor intensity	Unusual patterns	Juicy
Nutty		Dry
Grainy (cereal grain)		Cohesive
Fruity		Crumbly
Chalky		Rubbery
Woody		Soft

and a summary of comments made by the panelists.

TABLE 4: Results from Sensory Screening Panel for Ground Pork Patties with Added Source of Dietary Fiber (Refer to Table 1 for ingredient source).

INGREDIENT	LEVEL	SCORING	COMMENTS: FLAVOR	COMMENTS: COLOR	COMMENTS: TEXTURE
1	3.5%	8 A 0 R 0 M	Good Sl. grainy	Mottled Sl. light	Mealy/ Grainy Sl. dry* Cohesive Skin
1	10%	0 A 5 R 2 M	Sl. bland* No taste V. woody	Light* Speckled	Dry* Chewy* Tough Sl. grainy
2	3.5%	5 A 0 R 1 M	Woody Grainy Sl. off Good	Ok	Good bite Sl. rubbery*
2	10%	1 A 4 R 1 M	Woody Ok Bland*	Light* Non-uniform	Dry* Grainy Tough/ Hard
3	3.5%	6 A 0 R 1 M	Similar to control*	Good Light*	Good bite Good mouth-feel* Sl. rubbery* Sl. cohesive
3	10%	2 A 3 R 1 M	Bland* Woody Ok	Light* Mottled	Dry* Grainy Chewy

INGREDIENT	LEVEL	SCORING	FLAVOR	COLOR	TEXTURE
4	3.5%	5 A 0 R 3 M	Good*	White particles Mottled	Mealy/ grainy* Juicy Sl. tough Sl. rubbery*
4	10%	0 A 5 R 1 M	Woody Ok	Flaked appear- ance Gritty* particles Light	Dry* Crumbly
5	3.5%	0 A 7 R 0 M	Good* Bland Eggy Chalky	Light*	Mushy/ soft* Oily Doughy Sticky
6	3.5%	0 A 8 R 0 M	Lacking Bland*	Yellow tint	Slick* Crumbly Mushy/ soft* Sticky* Oily* Tacky
7	3.5%	0 A 7 R 0 M	Bland* Good Woody	Light yellow Light	Mushy/ soft Oily Sticky* Crumbly Oatmeal -like
8	3.5%	6 A 0 R 0 M	Ok Bland		Gluey Sl. Soft* Sl. Grainy* Mushy Good Mouth- feel

INGREDIENT	LEVEL	SCORING	FLAVOR	COLOR	TEXTURE
8	10%	3 A 1 R 2 M	Nutty Ok* Sl. bland Sweet	Ok	Gummy Pasty Sl. mushy* Dry* Soft
9	3.5%	2 A 2 R	Ok Lacks flavor Sl. rancid	Sl. dark*	Dry* Rubbery* Tough
9	10%	1 A 5 R 1 M	Off flavor Ok V. bland Woody	Dark Spotted Patterns Two-toned	Dry* Gritty Tough Rubbery Grainy
10	3.5%	7 A 0 R 0 M	Sl. off Ok Sl. bland Good flavor	Ok	Ok floury Sl. rubbery
10	10%	1 A 3 R 2 M	Cereal* Off flavor Ok Bland/ chalky*	Light* 2-toned* Ok	Dry* Mushy* Good bite Mealy
11	3.5%	7 A 0 R 1 M	Bland Ok Off flavor Chalky	Mottled	Oily* Sl. mushy* Sl. soft* Tacky
11	10%	1 A 4 R 1 M	Sl. off Woody Ok Bland*	2-toned Yellow surface Light	Dry* Mealy* Crumbly Mushy/ soft* Floury

INGREDIENT	LEVEL	SCORING	FLAVOR	COLOR	TEXTURE
12	3.5%	0 A 6 R 0 M	Bland* Neutral Masks pork flavor Ok	Ok Dark spots	Mushy/ soft* Oily Slick Pasty Crumbly
13	3.5%	1 A 4 R 1 M	Fruity Woody Ok Bland*	Good Small particles present	Mushy/ soft* Dry*
14	3.5%	4 A 2 R 1 M	Ok* Sl. woody Nutty	Sl. dark	Mushy* Low bind Crumbly Soft* Tacky* Gritty
15	3.5%	6 A 0 R 1 M	Ok*	Dark*	Sl. dry* Good Rubbery* Sl. Crumbly
16	3.5%	3 A 2 R 1 M	Off flavor No pork flavor Good flavor Cereal	Lighter	Soft Sl. dry Mealy
17	3.5%	1 A 4 R 1 M	Off flavor* Eggy Bland Chalky	Splotchy*	Gooey Mushy* Grainy Pasty Sl. crumbly
18	3.5%	1 A 6 R 1 M	Off odor* Burnt flavor Fruity Sweet	Dark*	Sticky Soft Crumbly Mealy/ grainy

INGREDIENT	LEVEL	SCORING	FLAVOR	COLOR	TEXTURE
19	3.5%	2 A 3 R 3 M	Cereal* Nutty Fruity	Dark*	Grainy* Rubbery* Good* Juicy
20	3.5%	2 A 4 R 2 M	Sweet odor Off flavor Sl. nutty Cereal* Chalky	Dark*	Mealy/ grainy* Sl. rubbery* Cohesive
21	3.5%	2 A 4 R 0 M	Off flavor Off odor Fruity odor Cereal Sweet Nutty	Orange tint Dark*	Powdery Dry
22	3.5%	0 A 7 R 1 M	Nutty Off flavor* Cereal*	Sl. dark* Unusual color patterns	Rubbery* Firm/ cohesive Sl. dry
23	3.5%	1 A 1 R 4 M	Cereal* Woody Fruity Nutty*	Good	Dry Sl. mushy Good*
24	3.5%	1 A 4 R 1 M	Bland	Yellow Light	Mushy Mealy* Dry* Crumbly* Sandy
25	3.5%	3 A 0 R 4 M	Sl. woody Bland Good Off flavor	Normal	Grainy Dry* Tough* Rubbery* Chewy

INGREDIENT	LEVEL	SCORING	FLAVOR	COLOR	TEXTURE
25	10%	0 A 6 R 1 M	Off flavor Woody* Grainy* Bland*	Ok Light	Dry* Grainy* Tough Gritty*
26	3.5%	2 A 3 R 1 M	Sl. off flavor Cereal* Nutty*	Unusual color patterns	Grainy* Flaky* Gritty Dry*
27	3.5%	4 A 2 R 0 M	Nutty* Off flavor* Sl. woody Good Floury		Grainy Sl. rubbery Sl. dry Gritty
27	10%	1 A 5 R 1 M	Woody Grainy* Burnt flavor Nutty Off flavor	Dark* Dark gold	Crumbly Sl. dry Gritty Good
28	3.5%	3 A 3 R 0 M	Off flavor Sl. woody Nutty	Sl. dark Good	Oily Good
28	10%	2 A 2 R 2 M	Fruity Sweet Woody	Ok Dark*	Ok Mushy* Grainy* Less chewy Soft Better than control

A = Accept; R = Reject; M = Maybe
* indicates same comment from more than one panelist.
"Sl." = Slightly
"V." = Very
Note that those samples without data at the 10% level were not evaluated at this level because of their less acceptable scores at the 3.5% level of added fiber.

The pure cellulose ingredients resulted in good panel acceptance. The products at 3.5% were more acceptable than products at 10% for all four (1-4) of the celluloses. Both products containing microcrystalline cellulose (No. 10 and 11) had high acceptability scores at 3.5% . The Nutriloid products ranged form acceptable to very unacceptable. Among the products formulated with the Nutriloid fibers (No. 12-15), products containing Nutriloid Colloid 710 had the highest acceptability scores and the guar fine and guar coarse products had the lowest acceptabilities. Products containing hydroxypropylmethylcellulose / maltodextrin also had high acceptability scores but rather low total fiber content which ranged from 20% to 40%.

The grain, fruit and vegetable based fibers were not selected for further study because of their generally low acceptability scores. A definite cereal flavor and odor was the main rejection factor. Nutty,

sweet and woody flavors also were commonly associated with these fibers. Dupro's vegetable fiber (No. 16) and Riviana Foods' rice bran (No. 27) tended to be more acceptable than the other grain, fruit and vegetable based fibers. However, the total fiber content of these fiber sources tend to be low.

In general, the cellulose products were slightly dry and mealy at the 3.5% level. These characteristics were accentuated at the 10.0% fiber level. The soluble fibers tended to make the meat products soft and mushy. This was especially evident for the carboxymethylcellulose products.

CONCLUSIONS

Based on overall evaluation scores and total dietary fiber content of ingredients, the products containing Solka-floc (BW-300), microcrystalline cellulose (RC-591) and Nutriloid Fiberplus were selected for further research.

Nutriloid Colloid 710 was not selected, although it had higher acceptability scores than Nutriloid Fiberplus, because of price difference and total fiber content. The Colloid 710 cost $6.00/lb and contained

78% total dietary fiber whereas the Fiberplus cost $3.95/lb and contained 95% total dietary fiber (prices based on 1987 figures).

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Paper 2

SENSORY ANALYSIS OF FIBER FORMULATED GROUND PORK PATTIES

S.L. Todd and F.E. Cunningham

Department of Animal Sciences and Industry
Kansas State University
Manhattan, Kansas 66506

Contribution No. , Department of Animal Sciences and Industry, Kansas Agricultural Experiment Station, Manhattan, KS 66506

---------------------- **ABSTRACT** ----------------------

Pure cellulose (Solka-Floc), microcrystalline cellulose (Avicel), and a soluble gum (Nutriloid Fiberplus) were added to ground pork (25% + 2% fat) at 3.5% and 7.0% based on total dietary fiber content of each ingredient. The formulated patties were presented to a professional sensory panel and evaluated for the following six attributes: resistance to bite, juiciness, off flavor, pork flavor intensity, graininess/flouriness and cohesiveness. Products containing Nutriloid Fiberplus at 3.5% and 7.0% had the least resistance to bite (softest) but no differences were detected between the two levels of these products. The Avicel and Solka-Floc products were statistically similar to the control products for resistance to bite. Products containing Nutriloid Fiberplus carried a significant off-flavor while products containing Avicel at 3.5% maintained a flavor similar to the control products. Products with Solka-Floc or Nutriloid Fiberplus had distinct graininess/flouriness attributes. Solka-Floc products and Nutriloid products were significantly more cohesive than control products. Avicel products at 3.5% were statistically similar to control products for all attributes evaluated.

INTRODUCTION

The food industry is continually developing new products and improving existing ones to cater to the consumer and their increased interest with health and nutrition. Therefore, research concerning dietary fiber in food systems has become increasingly important.

Very few studies have been done concerning the use of fiber in meat products. Currently small amounts of celluloses are being added to processed meats because of their water holding capacities. Solka-Floc (James River Corp.) employed at 0.5% to 1.0% shows 1.0% to 3.0% increase in patty yields while reducing patty shrink 1.0% to 1.5% (Bacus, 1986). FMC Corporation also has reported successful usage of MCC in fine grind meat emulsions at levels of 0.5% (Ayling, 1985). However, these amounts are far below the levels where fiber could play a significant role from a nutritional standpoint. If processors are interested in marketing a meat product with a high fiber claim, research must be done on formulated meat-fiber systems at fiber levels of 3.5% or greater. When adding 3.5% (meat block basis) of a fiber ingredient containing 95% to 100% total dietary fiber, a 85 gram (3 ounce) serving of meat will contain at least

the recommended three grams of dietary fiber per serving (Best, 1987).

The objective of this study was to evaluate the effect of three dietary fiber sources at addition levels of 3.5% and 7.0% on sensory characteristics of ground pork patties.

MATERIALS & METHODS

Experimental design

A two-way treatment structure with an added control in a split-plot design structure was used to evaluate the effect of dietary fiber on sensory properties of ground pork patties (Table 1). Five panelists tasted each treatment combination. The dietary fibers were added to coarsely ground pork picnic shoulders. The amount of fiber added equalled either 3.5% or 7.0% based on total dietary fiber content of each ingredient. The fibers studied were: (1) Solka -Floc BW-300, a pure cellulose (James River Corp., Berlin, NH.), (2) Avicel RC-591, a colloidal microcrystalline cellulose/ carboxymethylcellulose combination (FMC Corp., Newark, DE.), and (3) Nutriloid Fiberplus, a mixture of soluble gums (TIC Gums, New York, NY.). The reference control treatment was ground pork picnic shoulders with no fiber

added. All treatments contained 1.0% NaCl, 0.3% tripolyphosphate (CuraFos 22-4, FMC Corp.) and 25% + 2% fat. Four independent replications were made for each treatment-level combination.

TABLE 1: Treatment structure for the study of the effect of dietary fibers on texture and cooking properties of ground pork patties.

LEVEL %	Treatment (Ingredient) C	A	P	Z
0	C(0)	----	----	----
3.5	----	A(3.5)	P(3.5)	Z(3.5)
7.0	----	A(7.0)	P(7.0)	Z(7.0)

A = Avicel RC-591; P = Solka-Floc BW-300; Z = Nutriloid Fiberplus

Product preparation

Boneless frozen pork picnic shoulders (Flint Hills Foods, Alma, KS) were thawed at 2 C and then ground once through a 3/4 inch Hobart grinder plate (Hobart Mfg. Co.). The ground meat was vacuum packaged in eight pound units and frozen in a blast freezer (0 C). Eight

pound units were stored no more than 10 days. Meat was then ground through a 1/4 inch Hobart grinder plate and a 1.0% NaCl / 0.3% phosphate (CuraFos 22-4; Stauffer Chemical, Westport, CT.) mixture was sifted onto flattened meat block and briefly mixed into the meat by hand. Meat was ground a second time through a 1/4 inch plate to facilitate mixing. The unhydrated dietary fiber ingredients were mixed into the meat units for 1.5 min. with a dough hook attachment on a Hobart mixer (Hobart Mfg. Co.). Formulated product was hand stuffed in fibrous 5N X 24 pre-stuck casings (Viskase Corp., Chicago, Ill.) to form a meat log, which was pulled tight with a polyclip (40 psi; Niedecker GMBH, West Germany) and frozen for later cooking and sensory evaluation.

Proximate composition

Fresh ground pork picnics were analyzed by AOAC methods. The raw meat contained 58.5% water, 24.4% fat and 15.3% protein. Cooked products containing the dietary fibers were analyzed for fiber content utilizing a modified form of the Prosky method (Sigma Chemical, 1985) for total dietary fiber.

Sensory evaluation

Frozen meat logs were thawed at 2 C overnight and cooked on wire racks in a 121 C rotary oven until center of log reached an internal temperature of 71.1 C. Logs were cooled to room temperature and sliced with a deli-style slicer (Berkel, La Porte, Ind.) into 1.58 cm. slices. Patties were cut into eight wedges and two wedges were served warm (40 C) to each panelist. Four complete replications of treatment-level combinations were evaluated by a trained professional panel consisting of five panelists. Panelists evaluated each treatment-level combination for six attributes (Resistance to bite; very low.....very high, (Berry et al., 1983) Juiciness; very dry.....very juicy, (Berry et al., 1983) Off flavor; none.....abundant, Pork flavor intensity; none.....intense, Grainy/Floury; none.....abundant, Cohesiveness; very low.....very high (Berry et al., 1983) utilizing a 16.2 cm visual analog scale (Maxwell, 1978) with anchored control (Figure 1).

Products were presented over four days, with each day containing a complete replication. Each day was divided into two sessions where panelists evaluated only four randomly selected treatments in each session. Each session contained a randomly placed control treatment

FIGURE 1: Example score card for sensory analysis of fiber formulated ground pork patties.

RESISTANCE TO BITE (first bite)

C

|________________________M______________|_________|

VERY LOW VERY HIGH

JUICINESS (7-10 chews)

C

|________________________M____|___________________|

VERY DRY VERY JUICY

OFF-FLAVOR

C

|________________________M________________________|

NONE ABUNDANT

PORK FLAVOR INTENSITY

C

|________________________M________________________|

NONE INTENSE

GRAINY/FLOURY

C

|________________________M________________________|

NONE ABUNDANT

COHESIVENESS (15 chews)

C

|________________________M_________|______________|

VERY LOW VERY HIGH

* This form is only an example. The original score card had lines that were 16.2 cm. long.

(Table 2). Panelists were seated in a specially constructed room free from noise and odors. Individual booths were lighted with low-intensity red light to mask possible cooked color differences.

TABLE 2: Testing scheme used for presenting fiber formulated pork products to taste panel.

	SESSION 1				SESSION 2			
REPLICATION 1	P	Z	C	A*	C	Z*	A	P*
REPLICATION 2	Z*	A*	C	Z	P*	P	C	A
REPLICATION 3	P*	C	A	Z*	P	Z	A*	C
REPLICATION 4	P	P*	Z*	C	A	C	A*	Z

C = Control; A = Avicel; P = Pure cellulose (Solka-Floc); Z = Nutriloid Fiberplus

* 7.0% level of fiber ingredient; those letters without stars are either control products or products containing 3.5% of respective fiber.

Statistical analysis

The responses of four evaluations per treatment-level combination for each panelist were tested employing analysis of variance techniques. Comparisons among tasters were made for each treatment. Comparisons among treatments were also made for each taster. Consistency of the two panel sessions were tested by comparing the control responses from each session.

RESULTS AND DISCUSSION

Proximate Composition

The cooked products were analyzed for total dietary fiber content (Table 3). Fat, protein, ash and moisture were also determined on the cooked products. The modified Prosky method by Sigma Chemical Company worked well for the cellulose products (Avicel and Solka-Floc). However, only about half of the fiber in the soluble gum product (Nutriloid Fiberplus) was recovered for analysis.

Treatment comparisons

Resistance to bite (TABLE 4): Products containing Nutriloid Fiberplus were softer ($P < 0.05$) than other products. Although there were some discrepancies among

panelists, the majority (three out of five panelists) showed no significant difference among controls, Avicel and Solka-Floc products. Two panelists indicated that products containing Avicel at 7.0% were more resistant ($P < 0.05$) to bite than Solka-Floc products at 3.5% and 7.0%. However, they found no difference ($P > 0.05$) from control products for both Avicel and Solka-Floc products.

TABLE 3: Percentage of fat, protein, ash, moisture and total dietary fiber content of cooked products.

Product	% Moisture	% Fat	% Protein	% Ash	% TDF/85g.
P(3.5%)	50.72	22.84	16.40	1.90	3.61
P(7.0%)	49.26	21.84	17.54	1.76	6.56
A(3.5%)	52.20	23.80	18.15	2.03	3.80
A(7.0%)	49.50	21.57	17.22	2.13	6.64
Z(3.5%)	53.16	21.23	21.34	2.34	1.80
Z(7.0%)	50.68	25.34	18.22	2.19	3.37

P = Solka-Floc; A = Avicel; Z = Nutriloid Fiberplus

TDF = Total dietary fiber

Juiciness (TABLE 5): Level of fiber ingredient didn't affect juiciness of the product ($P > 0.05$). In fact, no one treatment combination was consistently different ($P < 0.05$) from any other treatment combination. Although the control products were generally marked as juicier than the other products tested, only one panelist found the control to be more juicy ($P < 0.05$) than products containing Solka-Floc, Nutriloid Fiberplus and Avicel at 7.0%.

Off-flavor **(TABLE 6):** The Nutriloid Fiberplus products tended to have more off-flavor than all of the other products. However, the Fiberplus products at 3.5% and 7.0% were different ($P < 0.05$) from only the control products. Generally, level of fiber ingredient did not affect degree of off-flavor. However, two panelists found the 7.0% Avicel product to have more off-flavor ($P < 0.05$) than products containing 3.5% Avicel. Only the product containing 3.5% Avicel was consistently similar to control products.

Pork flavor intensity (TABLE 7): Added fiber ingredients tended to dilute the natural pork flavor of the meat. Using the Nutriloid products and, in some cases, the Solka-Floc products caused the least pork flavor detected. The Avicel products were not

different ($P > 0.05$) from the control products except for one instance where the 7.0% Avicel product (panelist 3) had less pork flavor ($P < 0.05$) than control products. Off-flavor and pork flavor intensity showed an inverse relationship in this study.

Grainy/Floury (TABLE 8): All panelists found the Nutriloid products to be more grainy or floury ($P < 0.05$) than the control products. In all cases the 3.5% Avicel product was not different ($P > 0.05$) from the control products. All panelists found both levels of Solka-Floc products to be more grainy or floury ($P < 0.05$) than the control products. In general, level changes within ingredients tended to effect the degree of graininess or flouriness detected.

Cohesiveness (TABLE 9): Cohesiveness was a difficult parameter to measure subjectively. Note the variability in the data, especially for panelists 4 and 5. Four panelists found no difference ($P > 0.05$) between Avicel products and control products. Different levels of use of Avicel products did not differ.

CONCLUSIONS

Products containing Avicel were most similar to the control products in all attributes tested. Solka-Floc

products tended to be drier, more grainy and had less pork flavor intensity. Nutriloid products tended to exhibit more off flavor, more graininess, flouriness and softness than the other products.

Level of fiber was a less important factor than type of fiber added. However, products containing 3.5% were more like control products for most attributes than were products containing 7.0% of the dietary fibers.

TABLE 4: Influence of fiber addition on the resistance to bite, as detected by sensory panelists, in fiber formulated ground pork patties.

TRT	TASTER 1	2	3	4	5
1	-1.25[a] (10.32)	-8.50[a] (6.59)	-6.50[bc] (6.81)	-6.75[a] (9.80)	-8.50[bc] (8.85)
2	-6.75[a] (16.09)	-21.25[a] (9.20)	-12.50[c] (12.61)	-19.75[a] (9.62)	-6.75[bc] (3.61)
3	10.25[a] (1.93)	-12.75[a] (4.66)	13.75[ab] (1.75)	-2.50[a] (4.13)	9.00[ab] (3.89)
4	7.00[a] (5.24)	-5.75[a] (7.33)	15.00[a] (3.81)	-10.25[a] (13.17)	16.00[a] (7.55)
5	-91.00[b] (3.19)	-75.50[b] (3.80)	-64.25[d] (5.44)	-90.00[b] (9.65)	-71.75[d] (7.76)
6	- 95.25[b] (1.11)	-82.25[b] (2.50)	-74.00[d] (7.15)	-100.75[b] (5.02)	-66.50[d] (20.06)
7	0.75[a] (4.75)	-6.50[a] (2.53)	0.75[abc] (5.76)	-3.25[a] (5.02)	3.75[abc] (1.60)
8	-6.50[a] (6.03)	-5.25[a] (1.11)	1.25[abc] (4.40)	-12.25[a] (7.06)	-12.00[c] (7.69)

Treatments (TRT): 1 = Solka-Floc (3.5%); 2 = Solka-Floc (7.0%); 3 = Avicel (3.5%); 4 = Avicel (7.0%); 5 = Nutriloid Fiberplus (3.5%); 6 = Nutriloid Fiberplus (7.0%); 7 = Control (Session 1); 8 = Control (Session 2).

(a,b,c,d) Means within columns having same superscript letter are not different ($P > 0.05$). MSE = 220.69

Values given in parentheses represent standard errors of means.

TABLE 5: Influence of fiber addition on the juiciness, as detected by sensory panelists, in fiber formulated ground pork patties.

TRT	TASTER 1	2	3	4	5
1	-9.50^{b} (9.40)	-19.75^{abc} (5.47)	-24.25^{bc} (3.75)	-51.75^{cd} (7.55)	-34.25^{bc} (7.59)
2	-0.50^{ab} (12.21)	-30.50^{bc} (8.57)	-30.00^{bc} (7.94)	-63.00^{d} (11.27)	-43.00^{c} (8.37)
3	-8.00^{b} (16.98)	-8.50^{ab} (10.65)	-12.75^{ab} (14.49)	-23.50^{ab} (17.85)	-12.00^{ab} (5.02)
4	-59.50^{c} (2.33)	-22.50^{abc} (11.05)	-42.00^{c} (9.19)	-36.00^{bc} (11.58)	-33.00^{bc} (8.61)
5	-3.50^{ab} (7.29)	-15.00^{ab} (15.83)	-21.25^{abc} (5.11)	-54.50^{cd} (9.31)	-43.25^{c} (9.11)
6	-10.75^{b} (3.07)	-40.00^{c} (3.06)	-31.50^{bc} (6.20)	-70.00^{d} (3.49)	-48.75^{c} (3.12)
7	18.25^{a} (3.04)	0.00^{a} (2.48)	1.25^{a} (3.07)	-4.00^{a} (3.67)	-17.75^{ab} (8.98)
8	4.25^{ab} (10.44)	-2.00^{a} (7.52)	-9.00^{ab} (2.61)	-3.25^{a} (3.20)	-4.25^{a} (3.92)

Treatments (TRT): 1 = Solka-Floc (3.5%); 2 = Solka-Floc (7.0%); 3 = Avicel (3.5%); 4 = Avicel (7.0%); 5 = Nutriloid Fiberplus (3.5%); 6 = Nutriloid Fiberplus (7.0%); 7 = Control (Session 1); 8 = Control (Session 2).

(a,b,c,d) Means within columns having same superscript letter are not different ($P > 0.05$). MSE = 278.09

Values given in parentheses represent standard errors of means.

TABLE 6: Influence of fiber addition on off flavor, as detected by sensory panelists, in fiber formulated ground pork patties.

TRT	TASTER 1	TASTER 2	TASTER 3	TASTER 4	TASTER 5
1	35.25^{b} (10.82)	60.50^{bc} (19.89)	140.00^{a} (8.55)	72.75^{b} (28.51)	19.25^{b} (9.55)
2	41.25^{b} (12.62)	54.50^{bc} (6.46)	148.75^{a} (5.27)	88.00^{ab} (17.72)	22.50^{b} (8.29)
3	11.25^{b} (2.59)	30.75^{cd} (17.59)	48.50^{b} (28.91)	4.75^{c} (1.75)	7.00^{b} (2.41)
4	26.25^{b} (4.13)	77.00^{ab} (18.37)	134.50^{a} (8.09)	29.75^{c} (9.10)	16.25^{b} (10.27)
5	108.00^{a} (13.07)	100.00^{a} (25.47)	129.50^{a} (25.18)	97.50^{ab} (17.98)	118.50^{a} (12.14)
6	100.25^{a} (21.57)	105.50^{a} (12.09)	150.25^{a} (2.75)	112.25^{a} (18.87)	136.50^{a} (5.84)
7	4.50^{b} (0.65)	14.25^{d} (2.84)	4.50^{c} (1.19)	12.75^{c} (9.76)	8.50^{b} (3.97)
8	8.25^{b} (2.02)	22.25^{cd} (3.47)	56.75^{b} (32.77)	8.50^{c} (3.28)	11.50^{b} (5.24)

Treatments (TRT): 1 = Solka-Floc (3.5%); 2 = Solka-Floc (7.0%); 3 = Avicel (3.5%); 4 = Avicel (7.0%); 5 = Nutriloid Fiberplus (3.5%); 6 = Nutriloid Fiberplus (7.0%); 7 = Control (Session 1); 8 = Control (Session 2).

(a,b,c,d) Means within columns having same superscript letter are not different ($P > 0.05$).
MSE = 760.69

Values given in parentheses represent standard errors of means.

TABLE 7: Influence of fiber addition on the pork flavor intensity, as detected by sensory panelists, in fiber formulated ground pork patties.

	TASTER				
TRT	1	2	3	4	5
1	-44.00^{a} (11.07)	-81.50^{c} (25.17)	-137.75^{c} (8.01)	-77.25^{bc} (26.05)	-63.75^{ab} (11.32)
2	-50.00^{a} (15.94)	-78.00^{bc} (18.68)	-146.75^{c} (6.50)	-114.50^{cd} (19.00)	-42.75^{ab} (7.98)
3	-23.75^{a} (6.50)	-33.50^{ab} (19.19)	-41.25^{ab} (22.22)	-24.50^{a} (14.22)	-30.25^{ab} (8.68)
4	-33.50^{a} (1.66)	-33.75^{ab} (59.05)	-136.50^{c} (8.47)	-32.00^{ab} (6.92)	-52.75^{ab} (10.08)
5	-120.75^{b} (15.41)	-108.50^{cd} (4.05)	-131.50^{c} (23.50)	-140.25^{d} (5.36)	-132.25^{c} (11.43)
6	-140.25^{b} (2.50)	-140.25^{d} (4.57)	-111.00^{c} (36.64)	-152.25^{d} (2.46)	-152.75^{c} (2.93)
7	-10.25^{a} (2.50)	-16.25^{a} (4.64)	-6.25^{a} (0.85)	-38.75^{ab} (25.44)	-17.50^{a} (5.87)
8	-11.50^{a} (4.56)	-28.75^{a} (5.25)	-55.50^{b} (33.49)	-8.75^{a} (7.43)	-69.75^{b} (10.00)

Treatments (TRT): 1 = Solka-Floc (3.5%); 2 = Solka-Floc (7.0%); 3 = Avicel (3.5%); 4 = Avicel (7.0%); 5 = Nutriloid Fiberplus (3.5%); 6 = Nutriloid Fiberplus (7.0%); 7 = Control (Session 1); 8 = Control (Session 2).

(a,b,c,d) Means within columns having same superscript letter are not different ($P > 0.05$). MSE = 1151.13

Values given in parentheses represent standard errors of means.

TABLE 8: Influence of fiber addition on the graininess and flouriness, as detected by sensory panelists, in fiber formulated ground pork patties.

	TASTER				
TRT	1	2	3	4	5
1	103.50^{a} (11.51)	55.00^{b} (13.90)	92.25^{bc} (18.35)	72.00^{c} (26.39)	44.50^{cd} (24.63)
2	104.00^{a} (3.03)	71.25^{b} (18.05)	118.75^{ab} (3.25)	125.00^{ab} (11.92)	62.25^{bc} (16.76)
3	17.00^{bc} (7.12)	14.00^{c} (5.51)	18.75^{d} (7.47)	5.00^{d} (1.41)	5.00^{e} (2.71)
4	46.25^{b} (27.27)	51.50^{b} (6.06)	79.00^{c} (21.70)	11.25^{d} (2.29)	28.50^{de} (8.70)
5	93.50^{a} (17.63)	82.25^{b} (6.61)	117.75^{ab} (2.25	110.00^{b} (13.93)	80.25^{b} (15.21)
6	123.25^{a} (3.64)	128.00^{a} (2.04)	126.00^{a} (2.68)	141.75^{a} (4.21)	131.75^{a} (3.71)
7	4.75^{c} (0.48)	9.50^{c} (0.87)	4.25^{d} (0.63)	15.25^{d} (11.28)	3.75^{e} (0.85)
8	11.50^{e} (7.53)	19.00^{c} (6.68)	7.50^{d} (2.02)	5.75^{d} (2.75)	3.25^{e} (1.31)

Treatments (TRT): 1 = Solka-Floc (3.5%); 2 = Solka-Floc (7.0%); 3 = Avicel (3.5%); 4 = Avicel (7.0%); 5 = Nutriloid Fiberplus (3.5%); 6 = Nutriloid Fiberplus (7.0%); 7 = Control (Session 1); 8 = Control (Session 2).

(a,b,c,d,e) Means within columns having same superscript letter are not different ($P > 0.05$). MSE = 486.44

Values given in parentheses represent standard errors of means.

TABLE 9: Influence of fiber addition on the cohesiveness, as detected by sensory panelists, in fiber formulated ground pork patties.

TRT	TASTER 1	TASTER 2	TASTER 3	TASTER 4	TASTER 5
1	12.50^{bcd} (3.75)	-3.75^{bc} (8.04)	7.75^{abc} (7.00)	-37.75^{b} (18.74)	1.25^{a} (2.93)
2	21.25^{bc} (3.33)	3.50^{bc} (8.43)	8.75^{cd} (9.78)	-82.33^{c} (30.78)	6.75^{a} (2.95)
3	-1.25^{cd} (3.22)	-4.50^{bc} (3.38)	-8.50^{cd} (8.21)	-6.75^{a} (3.15)	4.00^{a} (2.04)
4	14.50^{bcd} (5.63)	-5.75^{bc} (9.10)	-22.75^{d} (15.46)	-10.00^{a} (2.12)	4.75^{a} (3.33)
5	28.50^{b} (2.33)	11.50^{ab} (3.12)	20.75^{ab} (4.31)	-77.00^{c} (5.90)	9.75^{a} (4.61)
6	60.00^{a} (25.05)	26.50^{a} (2.40)	23.50^{a} (3.77)	-94.75^{c} (2.59)	13.75^{a} (0.95)
7	-2.25^{d} (4.25)	-7.75^{bc} (2.56)	3.75^{abc} (4.50)	-5.75^{a} (4.87)	-1.50^{a} (1.26)
8	-7.50^{d} (1.32)	-11.50^{c} (3.80)	0.25^{bc} (5.89)	-8.00^{a} (8.57)	0.50^{a} (0.50)

Treatments (TRT): 1 = Solka-Floc (3.5%); 2 = Solka-Floc (7.0%); 3 = Avicel (3.5%); 4 = Avicel (7.0%); 5 = Nutriloid Fiberplus (3.5%); 6 = Nutriloid Fiberplus (7.0%); 7 = Control (Session 1); 8 = Control (Session 2).

(a,b,c,d) Means within columns having same superscript letter are not different ($P > 0.05$).
MSE = 262.79

Values given in parentheses represent standard errors of means.

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Paper 3

THE EFFECT OF DIETARY FIBER ON THE TEXTURE AND COOKING CHARACTERISTICS OF GROUND PORK

S.L. Todd and F.E. Cunningham

Department of Animal Sciences and Industry
Kansas State University
Manhattan, Kansas 66506

Contribution No. , Department of Animal Sciences and Industry, Kansas Agricultural Experiment Station, Manhattan, KS 66506

---------------------- **ABSTRACT** ----------------------

Pure cellulose (Solka-Floc), microcrystalline cellulose (Avicel), and a soluble gum (Nutriloid Fiberplus) were added to ground pork at 3.5% and 7.0% based on total dietary fiber content of each ingredient. Texture and cooking characteristics were determined on the formulated patties and compared to a control. Texture attributes were analyzed using the Universal Instron Testing Instrument and the texture profile analysis method. The two cellulose products at 3.5% most closely resembled the control while the gum product at both 3.5% and 7.0% was much softer. The two cellulose products at 7.0% exhibited more hardness while the gum products at 3.5% and 7.0% showed less springiness (elasticity). Cooking losses declined as fiber concentration increased from 3.5% to 7.0% for the cellulose products. Cooking losses increased for the gum products. The Avicel products at 3.5% and 7.0% and Solka-Floc product at 7.0% exhibited significantly less patty shrinkage.

INTRODUCTION

The food industry is continually developing new products and improving existing ones to cater to the consumer and their increased interest in health and nutrition. Therefore, research concerning dietary fiber in food systems has become increasingly important.

Very few studies have been done concerning the use of fiber in meat systems. Currently small amounts of celluloses are being added to processed meats because of their water holding capacities. Solka-Floc (James River Corp.) employed at 0.5% to 1.0% shows 1.0% to 3.0% increase in patty yields while reducing patty shrink 1.0% to 1.5% (Bacus, 1986). FMC Corporation also has reported successful usage of MCC in fine grind meat emulsions at levels of 0.5% (Ayling, 1985). However, these amounts are far below the levels where fiber could play a significant nutritional role. If processors are interested in marketing a meat product with a high fiber claim, research must be done on formulated meat-fiber systems at fiber levels of 3.5% or greater. When adding 3.5% (meat block basis) of a fiber ingredient containing 95% to 100% total dietary fiber, an 85 gram (3 ounce) serving of meat will contain at least the recommended three grams of dietary fiber per serving (Best, 1987).

The objective of this study was to evaluate the effect of three different dietary fiber sources at addition levels of 3.5% and 7.0% on the texture and cooking parameters of ground pork patties.

MATERIALS & METHODS

Experimental design

A two-way treatment structure with an added control in a randomized complete block design structure was used to evaluate the effect of dietary fiber on the texture and cooking properties of ground pork patties. The treatment structure is specified in Table 1. Dietary fibers were added to coarsely ground boneless pork picnic shoulders at 3.5% or 7.0% based on total dietary fiber content of each ingredient. The fibers studied were: (1) Solka Floc BW-300, a pure cellulose (James River Corp., Berlin, NH.), (2) Avicel RC-591, a colloidal microcrystalline cellulose / carboxymethylcellulose combination (FMC Corp., Newark, DE.), and (3) Nutriloid Fiberplus, a mixture of soluble gums (TIC Gums, New York, NY.). The reference control treatment was ground pork picnic shoulder meat with no fiber added. All treatments contained 1.0% NaCl, 0.3% tripolyphosphate (CuraFos 22-4, FMC Corp.) and 25% + 2%

fat. Four independent replications were made for each treatment-level combination.

Table 1: Treatment structure for the study of the effect of dietary fibers on texture and cooking properties of ground pork patties.

LEVEL %	Treatment (Ingredient) C	A	P	Z
0	C(0)	----	----	----
3.5	---	A(3.5)	P(3.5)	Z(3.5)
7.0	----	A(7.0)	P(7.0)	Z(7.0)

A = Avicel RC-591; P = Solka-Floc BW-300; Z = Nutriloid Fiberplus

Product preparation

Boneless frozen pork picnic shoulders (Flint Hills Foods, Alma, KS) were thawed at 2 C and then ground once through a 3/4 inch Hobart grinder plate (Hobart Mfg. Co.). The approximate composition of the fresh meat was 58.5% water, 24.4% fat and 15.3% protein. The ground meat was vacuum packaged in eight pound units and frozen in a blast freezer (0 C). Eight pound units were stored

no more than 10 days. Meat was then ground through a 1/4 inch Hobart grinder plate and a 1.0% NaCl - 0.3% phosphate (CuraFos 22-4; Stauffer Chemical, Westport, CT.) mixture was sifted onto flattened meat block and briefly mixed into the meat by hand. Meat was ground a second time through a 1/4 inch plate to facilitate mixing. The unhydrated dietary fiber ingredients were mixed into the meat units for 1.5 min. with a dough hook attachment on a Hobart mixer (Hobart Mfg. Co.). Part of the formulated sample was vacuum packaged in small Cryovac bags and frozen to be later made into patties for cooking tests. The rest of the sample was hand stuffed in fibrous 5N X 24 pre-stuck casings (Viskase Corp., Chicago, Ill.) to form a meat log, which was pulled tight with a polyclip (40 psi; Niedecker GMBH, West Germany) and frozen for later instrumental evaluation.

Instrumental evaluation

Frozen meat logs were thawed at 2 C overnight and cooked on wire racks in a 121 C rotary oven until center of log reached an internal temperature of 71.1 C. Internal temperatures were monitored by thermocouples. Logs were cooled to room temperature and sliced with a

deli-style slicer (Berkel, La Porte, Ind.) into 1.58 cm. slices. Two 2.54 X 1.58 cm. cores were taken from each of three randomly selected slices and compressed to 75% of their original height (Brady et al., 1985) using a 5.68 cm. diameter plunger attached to an Universal Instron Testing Instrument, Model 4201. A 500 kg. load cell was used with crosshead and chart speeds of 20 mm/min. Each core was compressed twice to give a "two bite" work-force compression curve. Six samples were tested from each replication. Texture parameters were derived from the curves as described in Table 2.

Cooking properties

Vacuum packaged samples were thawed, formed into uniform 85 gram patties and oven broiled on wire racks in a 191 C rotary oven for 50 min. or until first loss of pinkness in patty center. Twelve patties of each treatment combination were individually weighed before and after broiling to determine cook yield, which was expressed as (weight of cooked patty/weight of raw patty) X 100 (Means et al., 1987). Volatile loss and drip loss were also determined by gravimetric methods (Berry et al., 1983). Patty shrinkage was determined by taking the average diameter change for each nine cm.

patty after cooking. Percentage of thickness change was estimated by measuring average patty height before and after cooking.

Table 2: Interpretation methods for texture profile parameters from Instron curves.

Texture parameter	Curve interpretation
HARDNESS	Maximum force of first compression cycle (kg) (Bourne, 1968)
COHESIVENESS	Curve 2 area/ curve 1 area (Friedman et al., 1963)
SPRINGINESS	Downstroke width of curve 2 (Bourne, 1968)
FRACTURABILITY	Force at first significant break in curve (kg) (Bourne, 1978)

Statistical analysis

The average response of six core samples, two core samples from each of three slices, from each replication was analyzed for texture parameters. The average response of measurements on three patties from each

replication was analyzed for cooking characteristics. All average responses were tested employing analysis of variance techniques. In addition, an analysis of the rank of the average response, a nonparametric analysis procedure, was conducted when means were not normally distributed (Conover and Iman, 1976). Interaction among the treated groups was tested for in a two-way analysis of variance. For those response variables where treatment by level interaction was not significant, ($P > 0.05$; fracturability, springiness, swell), comparisons among the means of levels averaged over treatment and among means of treatments averaged over level were made.

Even though interactions were not detected at the 5% level of significance for some response variables (fracturability, springiness, swell), planned comparisons among the treated groups and with control were made and are reported. Treatment mean comparisons were made using least significant difference procedures when an overall F-test was significant ($P < 0.05$).

RESULTS AND DISCUSSION

INSTRON (TABLE 3)

Fracturability Data were analyzed by ranking

techniques due to the discrete nature of the response data. No significant differences were found among the control and products made with Solka-Floc at 3.5% and Avicel at 3.5% . Products containing 3.5% Solka-Floc had a higher fracturability ($P < 0.05$) than 7.0% Solka-Floc products, but no level differences were found for the products containing the other two ingredients. The lack of difference among fracturability scores for the control product and products containing Solka-Floc (3.5%) and Avicel (3.5%) indicated that the meat particles were still holding a firm structure. As fiber percentage increased from 3.5% to 7.0%, the intact structure seemed to be weakened to the point where very little if any fracturability occurred.

Considering the overall treatment means, no difference ($P > 0.05$) was found between fiber levels of 3.5% and 7.0%, but a difference ($P < 0.05$) was detected between no additive and the 3.5% and 7.0% levels. A significant difference was found between the control overall treatment mean and the Solka-Floc, Avicel and Nutriloid Fiberplus overall treatment means. However, the Solka-Floc, Avicel and Nutriloid Fiberplus overall means did not differ ($P > 0.05$).

Hardness Hardness was influenced by both type and quantity of fiber. Only products containing Nutriloid Fiberplus at 3.5% and Avicel at 3.5% were statistically similar to the control. The gum softened the sample considerably as fiber was increased and Avicel and Solka-Floc tended to make the product harder. However, Solka-Floc showed a much greater effect than Avicel. This could be attributed to the chemical composition of Avicel which is a colloidal microcrystalline cellulose-sodium carboxymethylcellulose mixture. This result supports the theory that by combining insoluble and soluble fiber sources an intermediary function can be achieved.

Cohesiveness Few differences were found among cohesiveness values for the products. The Nutriloid gum produced the lowest cohesiveness values. Products made with 7.0% Nutriloid Fiberplus had slightly less cohesiveness than the control whereas products made with Solka-Floc at the 7.0% level had slightly more cohesiveness. No differences ($P > 0.05$) were found among the other treatment combinations. The values corresponded quite well with the hardness data. In most cases, as the product became softer it was measured as

less cohesive and as it became harder it was measured as more cohesive.

Springiness Springiness had an inverse relationship to the actual springiness of the product. This term is the expression used to report degree of product recovery after the first compression cycle. Only products made with Nutriloid Fiberplus at 3.5% and 7.0% were less springy ($P < 0.05$) than the control. All other products showed similar recovery between compression cycles.

Considering the overall treatment means, no difference ($P > 0.05$) was found between fiber levels of 3.5% and 7.0% . However, a significant difference was found between the fiber overall treatment means. The Nutriloid Fiberplus overall treatment mean was less springy ($P < 0.05$) than the other overall treatment means. No difference ($P > 0.05$) was found among the overall treatment means of Avicel, Solka-Floc and control.

Table 3: Mean values of instrumental texture profile parameters

TRT	Fracture*[1] (kg)	Hardness (kg)	Cohesiveness (dimension-less)	Spring (cm)
	Instron Texture Profile Analysis Parameters			
Control	6.04[a] (2.19)	22.45[cd] (1.28)	0.2621[b] (0.02)	0.8879[c] (0.09)
A (3.5%)	1.88[ab] (1.47)	28.27[bc] (3.05)	0.2755[ab] (0.02)	0.9642[bc] (0.02)
A (7.0%)	1.41[b] (1.41)	33.70[b] (3.33)	0.2766[ab] (0.01)	0.9746[bc] (0.04)
P (3.5%)	4.96[a] (0.50)	33.70[b] (1.13)	0.2538[bc] (0.01)	0.9471[bc] (0.02)
P (7.0%)	0.00[b] (0.00)	47.27[a] (1.83)	0.3071[a] (0.00)	0.9367[c] (0.01)
Z (3.5%)	0.00[b] (0.00)	19.52[de] (1.16)	0.2521[bc] (0.01)	1.0796[ab] (0.03)
Z (7.0%)	0.00[b] (0.00)	13.98[e] (1.16)	0.2221[c] (0.00)	1.1987[a] (0.02)
MSE*[2]	27.94	16.65	0.0005	0.008

*[1] Reported conclusions based on analysis of rank technique as suggested by Conover and Iman (1976).
*[2] Mean squared error obtained from the analysis of variance used for LSD multiple comparisons of treatment groups.
(a,b,c,d,e) Means within columns having same superscript letter are not different (P > 0.05).
A = Avicel RC-591; P = Solka-Floc BW-300; Z = Nutriloid Fiberplus
Values given in parentheses represent standard errors of means.

COOKING CHARACTERISTICS (TABLE 4)

Total Cooking Loss Products made with Avicel and Solka-Floc had less ($P < 0.05$) cooking loss than the control sample. Generally, as the ingredient concentration increased in the product, the respective cooking loss decreased. However, products with both levels of Nutriloid Fiberplus were not different ($P > 0.05$) from the control, but the means for both levels were higher than the control. The decrease in cooking loss for products containing Avicel and Solka-Floc can be attributed to the water binding capabilities of these two ingredients. The soluble fibers also trap water within their gel matrix through hydrogen bonding. However, other factors may influence the amount of water held. The presence of other hydrogen bonding ingredients such as phosphates and sodium chloride tend to reduce bond sites available between the gum and water. The degree of heat processing may also effect the water held. Often heat will destroy the originally formed hydrogen bonds.

Volatile loss The percentage of volatiles lost during cooking were lowered ($P < 0.05$) by the Avicel and Solka-

Floc fibers. Products containing Nutriloid Fiberplus also tended to have less volatile loss.

Drip loss No differences ($P > 0.05$) in percentage drip loss were found between the control and products with Avicel and Solka-Floc. Only the products containing Nutriloid Fiberplus exhibited greater ($P < 0.05$) drip losses than the other products.

Diameter change All formulated patties had a diameter shrinkage of approximately 25% . Only the patties with 7.0% Solka-Floc shrunk less (21.65%, $P < 0.05$). Fiber addition did not effect patty shrinkage until high levels of fiber were reached.

Thickness change The increase of height during cooking was not affected by fiber addition. All patties had a 40% to 50% increase in height. A large variation was found within treatment averages. Differences between replication means were determined by constructed confidence intervals. For instance, the confidence interval for the comparison of Avicel (7.0%) and Nutriloid Fiberplus (3.5%) was calculated as (-0.353, 25.436) and the respective confidence interval for

Table 4: Mean values for cooking parameters.

TRT	% Cooking Loss	% Volatile Loss	% Drip Loss	% Diameter Change	% Thickness Change
	Cooking Yield Parameters				
Control	38.85 [a] (1.38)	26.15 [a] (1.23)	11.70 [b] (0.52)	26.60 [a] (0.70)	41.24 [a] (3.97)
A (3.5%)	34.98 [b] (0.86)	21.50 [cd] (0.10)	11.20 [b] (0.85)	24.73 [ab] (1.54)	41.18 [a] (5.36)
A (7.0%)	31.42 [c] (0.42)	19.70 [d] (0.10)	10.75 [b] (0.05)	23.78 [ab] (0.40)	52.03 [a] (4.53)
P (3.5%)	34.55 [b] (0.78)	22.30 [c] (0.90)	11.15 [b] (1.13)	25.20 [a] (0.00)	43.68 [a] (5.53)
P (7.0%)	31.63 [c] (0.39)	19.73 [d] (1.30)	11.20 [b] (1.10)	21.65 [b] (1.28)	40.28 [a] (4.19)
Z (3.5%)	40.72 [a] (0.25)	23.15 [bc] (0.48)	15.48 [a] (1.07)	26.68 [a] (1.68)	39.49 [a] (3.23)
Z (7.0%)	40.69 [a] (0.67)	25.35 [ab] (0.76)	14.98 [a] (0.93)	26.58 [a] (0.85)	48.87 [a] (3.32)
MSE*	2.50	2.43	3.51	4.51	75.34

MSE* Mean squared error obtained from the analysis of variance used for LSD multiple comparisons of treatment groups.

(a,b,c,d) Means within columns having same superscript letter are not different ($P > 0.05$).

A = Avicel RC-591; P = Solka-Floc BW-300; Z = Nutriloid Fiberplus

Values given in parentheses represent standard errors of means.

Nutriloid Fiberplus (3.5%) and Nutriloid Fiberplus (7.0%) was (-3.519, 22.269). These rather large intervals explain the nonsignificance found for the thickness changes among treatments.

Considering the overall treatment means, no significant difference was found among levels or among treatments.

SUMMARY

Avicel at 3.5% was the only additive that did not affect texture measurements. Patties containing Solka-Floc at 3.5% were similar to controls for all measurements except hardness. Solka-Floc (7.0%) was consistently harder and more cohesive than the other ingredients. Meat patties containing Nutriloid Fiberplus (7.0%) tended to be softer, less cohesive and lowest in springiness.

No interaction was found for the fracturability, springiness and percentage swell responses. This suggests that for these responses, a proportional change in response in all ingredients was observed with an increase in ingredient level. The interaction found for the hardness, cohesiveness, cooking loss, volatile loss, drip loss and shrinkage indicated a disproportionate

change in ingredient response as ingredient levels changed.

CONCLUSIONS

Avicel (3.5%) could be added to a ground pork product as a dietary fiber ingredient without any adverse texture effects. Pure cellulose (Solka Floc BW-300) may also work as an effective additive at 3.5% if the hardness characteristic could be modified or reversed by perhaps another additive. The 7.0% level for all fiber ingredients appeared to be too high for products formulated in this way.

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APPENDIX

STATISTICAL PARAMETERS

TASTE PANEL DATA

Between treatment comparisons were conducted employing the LSD procedure using Satterthwaite's (1971) approximate degrees of freedom with pooled error term.

TABLE A

Response: Resistance to bite

Source	Df		Sum of Squares	F value	Pr>F
DAY	3		1660.55		
SESSION	1		530.20		
TREATMENT	7		176356.72	60.96	0.0001
FIBER		3	156151.67	125.95	0.0001
LEVEL		1	305.99	0.74	0.3997
FIBER * LEVEL		2	267.66	0.32	0.7271
ERROR	20		8265.50		
TASTER	4		5219.29	7.23	0.0001
TRT * TASTER	28		6096.71	1.21	0.2484
FIBER * TASTER		16	5137.91	1.78	0.0453
LEVEL * TASTER		4	708.33	0.98	0.4218
FIBER * LEVEL * TASTER		8	250.47	0.17	0.9940
ERROR	96		17334.00		

TABLE B

Response: Juiciness

Source	Df		Sum of Squares	F value	Pr>F
DAY	3		2832.66		
SESSION	1		1086.76		
TREATMENT	7		34789.89	6.86	0.0003
FIBER		3	1463.05	0.67	0.5787
LEVEL		1	7255.92	10.01	0.0049
FIBER * LEVEL		2	1613.03	1.11	0.3481
ERROR	20		14495.22		
TASTER	4		16609.07	22.68	0.0001
TRT * TASTER	28		17180.81	3.35	0.0001
FIBER * TASTER		16	14098.37	4.81	0.0001
LEVEL * TASTER		4	101.00	0.14	0.9678
FIBER * LEVEL * TASTER		8	2981.44	2.04	0.0503
ERROR	94		17207.27		

TABLE C

Response: Off-flavor

Source	Df	Sum of Squares	F value	Pr>F
DAY	3	5840.81		
SESSION	1	722.95		
TREATMENT	7	238251.37	29.69	0.0001
FIBER	3	117136.46	34.06	0.0001
LEVEL	1	10605.90	9.25	0.0064
FIBER * LEVEL	2	4179.76	1.82	0.1874
ERROR	20	22929.00		
TASTER	4	77189.44	28.37	0.0001
TRT * TASTER	28	58844.86	3.09	0.0001
FIBER * TASTER	16	49519.91	4.55	0.0001
LEVEL * TASTER	4	4029.42	1.48	0.2141
FIBER * LEVEL * TASTER	8	5295.53	0.97	0.4618
ERROR	96	65310.50		

TABLE D

Response: Pork flavor intensity

Source	Df		Sum of Squares	F value	Pr>F
DAY	3		10072.73		
SESSION	1		103.11		
TREATMENT	7		274586.07	25.93	0.0001
FIBER		3	152118.35	33.52	0.0001
LEVEL		1	7842.77	5.18	0.0339
FIBER * LEVEL		2	1832.65	0.61	0.5554
ERROR	20		30256.76		
TASTER	4		30033.06	6.98	0.0001
TRT * TASTER	28		74796.54	2.48	0.0006
FIBER * TASTER		16	55916.79	3.25	0.0002
LEVEL * TASTER		4	1659.95	0.39	0.8184
FIBER * LEVEL * TASTER		8	17219.80	2.00	0.0543
ERROR	96		103274.40		

TABLE E

Response: Grainy / Floury

Source	Df		Sum of Squares	F value	Pr>F
DAY	3		5442.08		
SESSION	1		2014.60		
TREATMENT	7		308827.32	39.39	0.0001
FIBER		3	146570.58	43.62	0.0001
LEVEL		1	25427.78	22.70	0.0001
FIBER * LEVEL		2	572.50	0.26	0.7769
ERROR	20		22398.63		
TASTER	4		12026.45	8.52	0.0001
TRT * TASTER	28		27792.31	2.81	0.0001
FIBER * TASTER		16	19473.02	3.45	0.0001
LEVEL * TASTER		4	639.14	0.45	0.7703
FIBER * LEVEL * TASTER		8	7680.14	2.72	0.0096
ERROR	95		33541.60		

TABLE F

Response: Cohesiveness

Source	Df		Sum of Squares	F value	Pr>F
DAY	3		2623.09		
SESSION	1		637.21		
TREATMENT	7		2198.94	0.88	0.5424
FIBER		3	1381.80	1.28	0.3071
LEVEL		1	310.99	0.87	0.3629
FIBER * LEVEL		2	418.12	0.58	0.5676
ERROR	20		7175.22		
TASTER	4		54184.78	55.84	0.0001
TRT * TASTER	28		61518.37	9.06	0.0001
FIBER * TASTER		16	54825.93	14.13	0.0001
LEVEL * TASTER		4	4718.24	4.86	0.0013
FIBER * LEVEL * TASTER		8	1974.21	1.02	0.4285
ERROR	95		23045.60		

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INTERACTION TABLES
FOR INSTRON AND COOKING DATA RESPONSES

INSTRON DATA

TABLE A

Response: Fracturability*

Source	Df		Sum of Squares	F value	Pr>F
REP	3		65.21		
TREATMENT +	6		773.88	4.62	0.0052
FIBER ++		2	164.02	2.94	0.0788
LEVEL ++		1	142.59	5.10	0.0365
FIBER * LEVEL ++		2	159.18	2.85	0.0842
ERROR	18		502.91		

*Reported conclusions based on analysis of the rank technique as suggested by Conover and Iman (1976).

TABLE B

Response: Hardness

Source	Df		Sum of Squares	F value	Pr>F
REP	3		51.84		
TREATMENT +	6		2937.62	29.41	0.0001
FIBER ++		2	2283.34	68.57	0.0001
LEVEL ++		1	120.95	7.26	0.0148
FIBER * LEVEL ++		2	367.55	11.04	0.0007
ERROR	18		299.70		

+: Comparison of the seven fiber by level treatment combinations.

++: F-tests reported are with respect to the treated groups, without control.

TABLE C

Response: Cohesiveness

Source	Df		Sum of Squares	F value	Pr>F
REP	3		0.00		
TREATMENT +	6		0.02	5.26	0.0028
FIBER ++		2	0.01	8.65	0.0023
LEVEL ++		1	0.00	0.76	0.3959
FIBER * LEVEL ++		2	0.01	6.72	0.0066
ERROR	18		0.01		

TABLE D

Response: Springiness

Source	Df		Sum of Squares	F value	Pr>F
REP	3		0.01		
TREATMENT +	6		0.27	5.52	0.0021
FIBER ++		2	0.18	11.27	0.0007
LEVEL ++		1	0.01	1.17	0.2941
FIBER * LEVEL ++		2	0.02	1.19	0.3258
ERROR	18		0.15		

+: Comparison of the seven fiber by level treatment combinations.

++: F-tests reported are with respect to the treated groups, without control.

COOKING DATA

TABLE E

Response: Cooking Loss

Source	Df		Sum of Squares	F value	Pr>F
REP	3		4.09		
TREATMENT +	6		382.26	25.44	0.0001
FIBER ++		2	304.90	60.89	0.0001
LEVEL ++		1	28.31	11.31	0.0035
FIBER * LEVEL ++		2	14.24	2.84	0.0845
ERROR	18		45.07		

TABLE F

Response: Volatile Loss

Source	Df		Sum of Squares	F value	Pr>F
REP	3		14.56		
TREATMENT +	6		153.71	10.56	0.0001
FIBER ++		2	63.93	13.17	0.0003
LEVEL ++		1	3.15	1.30	0.2692
FIBER * LEVEL ++		2	26.27	5.41	0.0144
ERROR	18		43.68		

+: Comparison of the seven fiber by level treatment combinations.

++: F-tests reported are with respect to the treated groups, without control.

TABLE G

Response: Drip Loss

Source	Df		Sum of Squares	F value	Pr>F
REP	3		2.70		
TREATMENT+	6		94.90	4.50	0.0059
FIBER ++		2	92.01	13.10	0.0003
LEVEL ++		1	0.54	0.15	0.6996
FIBER * LEVEL++		2	0.37	0.05	0.9488
ERROR	18		63.24		

TABLE H

Response: Diameter change

Source	Df		Sum of Squares	F value	Pr>F
REP	3		17.20		
TREATMENT+	6		82.63	3.05	0.0307
FIBER ++		2	44.13	4.89	0.0202
LEVEL ++		1	14.06	3.11	0.0946
FIBER * LEVEL++		2	12.94	1.43	0.2645
ERROR	18		81.26		

+: Comparison of the seven fiber by level treatment combinations.

++: F-tests reported are with respect to the treated groups, without control.

TABLE I

Response: Thickness change

Source	Df	Sum of Squares	F value	Pr>F
REP	3	260.07		
TREATMENT[+]	6	551.33		
FIBER[++]	2	85.48	0.57	0.5769
LEVEL[++]	1	188.91	2.51	0.1307
FIBER * LEVEL[++]	2	245.80	1.63	0.2233
ERROR	18	1356.03		

+: Comparison of the seven fiber by level treatment combinations.

++: F-tests reported are with respect to the treated groups, without control.

GROUND PORK FORMULATED WITH DIETARY FIBER

by

SUSAN L. TODD

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ABSTRACT

Twenty eight sources of dietary fiber formulated into ground pork patties were analyzed by a sensory panel for the preliminary studies of this project. Three products containing pure cellulose, microcrystalline cellulose and a soluble fiber gum were selected for further study.

Pure cellulose (Solka-Floc), microcrystalline cellulose (Avicel) and a soluble gum (Nutriloid Fiberplus) were added to ground pork at 3.5% and 7.0% based on total dietary fiber content of each ingredient. Texture, cooking characteristics and sensory analysis determinations were made on the products and compared to control products. Texture attributes were analyzed by the Universal Instron Testing Instrument utilizing the Texture Profile Analysis method. Percentage cooking loss, volatile loss, drip loss, diameter change and thickness change were the cooking parameters recorded. A professional sensory panel evaluated products on resistance to bite, juiciness, off-flavor, pork flavor intensity, graininess/flouriness, and cohesiveness.

The two cellulose products (Solka-Floc and Avicel) at 3.5% most closely represented the control while the gum products at both 3.5% and 7.0% were much softer. The two cellulose products at their respective 7.0%

levels exhibited higher hardness scores while the gum products at 3.5% and 7.0% showed less springiness.

Cooking losses declined as fiber concentration increased for the cellulose products. Cooking losses increased for the gum products. The Avicel products at 3.5% and 7.0% and Solka-Floc products at 7.0% exhibited less change ($P < 0.05$) in patty thickness.

Products containing Nutriloid Fiberplus (gum) at 3.5% and 7.0% had the least resistance to bite (softest) but no differences were detected between the two levels of these products. The Avicel and Solka-Floc products were similar ($P > 0.05$) to the control products for this attribute. Products containing Nutriloid Fiberplus carried a significant off-flavor while products containing Avicel at 3.5% maintained a flavor similar to the control products. Products with Solka-Floc and products with Nutriloid Fiberplus had distinct graininess/flouriness attributes. Solka-Floc products and Nutriloid products were more cohesive ($P < 0.05$) than control products. Avicel products at 3.5% were similar ($P > 0.05$) to control products for all attributes evaluated.